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ABSTRACT

The demand and supply of baccalaureate degree engineers from 1975 to 1983 are assessed, with some analysis of the implications the declining birth rate will have beyond 1983. The study reveals a current (1975) shortage for all types of engineers as well as a considerable long-term shortage to 1983 because of the probable response to the energy crisis. The greatest need, numerically, will be for electric-electronics engineers, mechanical engineers, industrial engineers, and chemical engineers. There will also be a marked increase in demand for highly specialized types, such as energy production, biomedical, health systems, and aquaculture. The long-term decline in the number of college-age youth projected here indicates a severe and deepening shortage of trained engineers unless currently undertapped populations, such as women and minorities, are recruited. Some consideration is also given to the problem of obsolescence and the possible role that industry and the schools of engineering may play in reducing it. Recommendations are made for (1) encouraging more students to major in engineering, (2) placing more emphasis on in-service and continuing education to avoid obsolescence and upgrade personnel quality, and (3) not building more classrooms but making more funds available to upgrade teaching and lab equipment. (Author/LBH)

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A Study of Baccalaureate Engineering Demand and Supply in Pennsylvania:

Methodology and Findings

Pennsylvania Department of Education 1975

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Summary

This study attempts to assess the demand and supply of baccalaureate degree engineers for Pennsylvania from 1975 to 1983 with some analysis of the implications that the declining birth rate will have on demand and supply beyond 1983.

The study reveals a current (1975) shortage for all types of engineers as well as a considerable long-term shortage to 1983 because of the probable response to the energy crisis. The greatest need, numerically, will be for electrical-electronics engineers, mechanical engineers, industrial engineers and chemical engineers. More will be needed than will probably be produced between 1975 and 1983.

In addition, there will be a marked increase in demand for highly specialized types of engineers, especially those related to nuclear power generation and energy production and those needed to improve health delivery systems and food production, e.g., biomedical, health systems, aquaculture. There will also be a need for engineers engaged in mining.

The long-term decline in the number of college-age youth projected here indicates a severe and deepening shortage of trained engineers beyond 1983 unless currently under-tapped populations, such as women and minorities, are recruited. Aptitudinal and motivational requirements for satisfactory completion of an engineering curriculum place real constraints on the number that can be recruited and graduated. In addition, every effort should be made to make engineering education as efficient as possible to reduce the relatively high attrition rates historically associated with engineering as a major.

Some consideration is also given to the problem of obsolescence and the possible role that industry and the schools of engineering may play in reducing it. The point is made that the practice of discarding the "obsolescent" engineer is a waste of human resources and encourages the concept that an engineer is inflexible and not readily susceptible to job retraining or effective transfer of his/her knowledge and skills to a new type of work. It is suggested that the engineering curriculum may need to be re-evaluated, especially as it relates to training for flexibility in an age of rapid technological progress and change, since the engineer, by definition, has demonstrated that he/she is an effective learner by virtue of having successfully completed a baccalaureate or a graduate degree.

A far greater emphasis on in-service and continued education will have to be made, by industry and the schools of engineering, to prevent an excessively high rate of "quality substitution" in the face of shortages and, at the same time, unemployment for older "obsolescent" degree-holding engineers. Industry, historically, has always employed less qualified substitutes when degree-holding engineers were in short supply. This may prove a less adequate expedient in the face of the long-term, dwindling supply of degree engineers foreseen for at least the next quarter of a century.

The response to the energy crisis is seen as really getting underway in 1976 and as sharply increasing our need for mining, petroleum, electrical, mechanical, industrial, civil and, to some degree, chemical engineers over and above the needs that would have been otherwise projected. Nuclear engineering is also expected to be a very high need area, with food related and health related engineering also coming to the fore.

A discussion of the limitations of the study is given, e.g., national based estimates of out-migration, arbitrary residual estimates of the rate of in-migration, the assumption that Pennsylvania's response to the energy crisis will be much the same as projected for the nation.

The projections made in this study are reasoned estimates of what will occur given certain assumptions. They are not prophecies or predictions or goal statements. Events such as war, severe depression, radical shifts in government priorities, etc., can change the ultimate outcome as well as any efforts made by the State of Pennsylvania to reduce the shortages now foreseen.

The need is seen not as one of a lack of classroom space to train engineers but rather as a problem of recruiting. What is needed is an adequate number of students to meet projected needs during a possible period of declining interest in science and engineering along with a possible concurrent decline in mathematical aptitude and science achievement scores. The schools will need funds to upgrade their teaching and laboratory equipment to reflect the rapidly changing technology and needs of our society so that those produced will be maximally capable of meeting the needs. Recent financial difficulties and declining interest in engineering may well have resulted in a backlog of need for up-to-date equipment in the colleges of engineering.

The recommendations growing out of this study are:

1. Encourage more students to major in engineering. This is particularly true for the following areas:

    Electronic and Electrical Engineering
    Mechanical Engineering
    Industrial Engineering
    Chemical Engineering
    Civil Engineering
    Mining Engineering
    Nuclear Engineering
    Specialized areas such as Aquaculture, bio- and health delivery systems engineering

2. Place more emphasis by industry and schools of engineering on in-service and continuing education to avoid obsolescence and to upgrade the quality of engineers on the job.

3. Do not build more classrooms to educate engineers but make more funds available to upgrade teaching and lab equipment to reflect changes in technology and the needs of society.

PURPOSE OF STUDY

This study represents one response to the need of the State Council of Higher Education for information on the future demand for graduates in those professions for which a degree is either mandatory or normally required.

To date, studies have been made of the professions of law,[19] dentistry,[17] medicine,[11] public school teaching,[21] special education,[20] and college teaching.[18] A study of the need for allied health personnel, including nursing, is in progress. These studies are essential to the efforts of the Department of Education, the administration and the state legislature to come to grips with the problem of allocating monies and resources during this period of budgetary restraint, declining enrollments and of rising costs.

The author knows of one previous study of the need for engineers in Pennsylvania. It was concerned only with the projection of demand and did not deal with supply. Entitled Manpower Requirements for Engineers, Scientists and Technicians in Pennsylvania by 1970, it was prepared by Robert H. Ramsey of the College of Engineering and Architecture, The Pennsylvania State University, in May of 1962.[48] Unfortunately, the projection of 88,500 employed engineers in 1970 over a figure of 61,600 for 1960 has proven to be far greater than the actual 1970 figure of 64,114. It appears that the reasons for this discrepancy are, at least, twofold: First, the projection method used was an approximation of the 1960 and 1970 figures based on National Science Foundation statistics; and, second, the use of the National Science Foundation's highly optimistic assumptions concerning the coming decade, which were based upon the historical pattern of the 1950s, e.g., high-level economic activity, no serious recessions, no wars, state labor trends similar to nations, a continuation of the population growth rates of the 1950s.

It is to be hoped that the reader of this report will, therefore, keep in mind that manpower projections are just projections, nothing more. Not predictions of the future, they are, rather, a reasoned estimate of what will occur, given that certain assumptions are valid with regard to the events and forces operating during the period of projection and within the limitations of the available data concerning the number and characteristics of the members of the projected occupation.

ENGINEERING AS A PROFESSION

In contrast to the term "physician," the term "engineer" has no precise agreed upon meaning in our culture. An "engineer" may actually be someone without a formal degree in one of the disciplines known as the sciences of engineering; he or she may, in fact, have no training whatsoever that the average layman would normally think of as relevant. For example, an individual who operates a locomotive is referred to as an engineer, although no formal education is required, only a long apprenticeship by rising through the ranks of positions other than "engineer."

Attempts have been made to develop strict criteria by the engineering profession, most notably the Engineers Council for Professional Development of the Engineers Joint Council but have not yet been universally accepted or used by all data gatherers or employers. The definition used by the council defines an engineer as anyone with an engineering degree or holding state registration as a professional engineer and anyone holding professional-level membership in a society which provides for the acceptance of demonstrated professional competence in lieu of a formal engineering degree and who regards himself as an engineer. No existing data base has fully and completely realized the implications of this definition, although the National Engineers Register attempted to do so by surveying the members of professional societies,[25] and some refinement of 1970 census data engineering has been attempted using somewhat different criteria to identify engineers more precisely.[44,67]

Many companies will hire or promote an individual into a position labeled "engineer," even though the qualifications he or she possesses are not those of a graduate engineer. Such practices may be based on the individuals having mastered requisite skills and knowledge while on the job. There may also be a process of downgrading the requirements in the face of a shortage of degree-holding engineers. There may even be a simple process of making a job more attractive by giving it an impressive title, e.g., a janitor becomes a "sanitary engineer."

For whatever reason, it is clear that the engineering profession has a problem of identity; and the usual statistics on engineers reflect that fact, i.e., they are grossly inflated by the inclusion of those who hold no formal degree and who do not do work calling for the skills of a degree holding engineer. An as-yet-unavailable study by the National Science Foundation will undoubtedly clarify the issue of a more accurate count.[44]

A second problem for engineering as a profession seems to be that, currently engineers are primarily employed by basic industries, e.g., manufacturing, utilities, etc., and are, as a consequence, extremely subject to changes in the economic climate. Such factors as recession and changes in federal priorities, e.g., military spending, the aerospace projects and the energy crisis, rapidly and severely affect the employment of engineers.

Such rapid or severe fluctuations produce periods of relatively high demand or unemployment, especially among the older engineers (45 years and up), whose skills may have become obsolete or whose high salary may be deemed undesirable by management in a period of retrenchment.

Obviously, these problems are not readily resolved. The lack of a clear-cut identity resists easy solution, since the present loose use of "engineer" is strongly embedded in custom and precedent. The professional societies will be constantly faced with the issue of how to get industry, and society in general, to use the term "engineer" with more precision. Undoubtedly efforts have been, and are being, made to encourage governmental and other data gatherers and purveyors to define the engineering population in greater detail and with consistency as to definition. This may well be the area in which the professional societies of engineering and the Engineers Joint Council can have the greatest impact, other than seeking legislation to certify, and thus delimit, the use of the term.

The relatively narrow employment base that makes engineers relatively prone to cycles of high demand or unemployment could be ameliorated somewhat by an increasing use of engineers in contexts other than basic industries.

Service industries, such as education and health, and new areas or frontiers, such as the exploitation of the oceans for food and mineral resources, are increasingly calling for the services of trained engineers. This greater diversification, although relatively minor as yet, suggests that engineering may yet become more stable with regard to demand.

There has, for example, been a rising emphasis upon bioengineering in medicine, where there has been a marked growth in the implantation of pacemakers and artificial organs, the monitoring of the acutely ill, health diagnosis by computers and other instrumentation, and the rehabilitation of patients who would have otherwise died or been severely handicapped.[35] The future may well see an increased use of engineers in the total health delivery system itself, since the demands of national health legislation--it now seems inevitable--may well require the unique systems oriented skills of the trained engineer in the complex modern hospital and other settings.

The use of newer forms of technology in education is as yet in its infancy, but it seems clear that the cost of such technology is dropping rapidly. This will make computer-assisted instruction and other technologies more readily available to the schools. There is also the possible use of satellite, cable and other communications devices capable of learner feedback. Such devices would be useful in the continuing education of professionals in medicine, law and industry in general, plus in medical diagnosis and consultation in rural and remote areas. They will undoubtedly require the use of skilled engineers.

The energy crisis and the partly related food supply problem will also create an increased diversification of trained engineers including aquaculture[60] and those disciplines needed to develop new sources of energy and new ways to conserve fuel.[10] Although it is virtually impossible to predict accurately the development of such new fields, there is no doubt that the category "other engineers," will make up a large share of the projected or actual growth during the coming decades.

Most of the problems that humanity faces are caused, in part, by technology but are unlikely to be solved without the use of technology. Increased diversification in tasks, and even curricula, seems inevitable in light of this.

Occupational Mobility

This study and others cannot, and do not, take into consideration the fact that although many workers have engineering training and use their engineering training on their job, they are not labeled engineers. As a result, such workers are not normally counted as engineers by the census enumerator or by data gatherers in general.

As a consequence, not only are most figures concerning the number of engineers misleading because they include individuals who are not, by strict definition, engineers, they also do not include trained, fully qualified engineers whose occupational titles do not reflect that fact, e.g., administrators and managers.

The National Engineers Register survey of 1969 indicated that the great majority of engineers, strictly defined, was actually engaged in some kind of management or supervision of other people.[3,25] The proportions vary according to each field of engineering and according to the age of the engineer (See Engineering Manpower Bulletin, "The Engineer as a Manager," No. 25, September 1973, published by the Engineers Joint Council).[23] In addition, figures from a 1972 post-census survey show that over 480,000 engineers with college degrees were reported by the 1970 census to be working under other occupational categories. An informal estimate conveyed to the author of this report by federal personnel working on the occupational mobility problem suggests a dropout rate of five per cent from the engineering ranks as a whole.

In any event, giving engineers managerial responsibility and different occupational labels represent a hidden demand for engineers that cannot be assessed here because of a lack of hard data. The estimates of need found at the end of this report are necessarily underestimates. As indicated earlier, the National Science Foundation's study of the 1972 Post-Censal Survey results may help resolve the matter when it becomes available.[44]

Women in Engineering

Historically, engineering has been an almost exclusively male profession. The declining enrollment of males in engineering, the recent focus on equality of opportunity in employment, the recognition by some in industry of a need for engineers with people-oriented skills as well as technical skills, the high demand for engineers over and above supply and the dwindling of opportunities for graduates in those field usually entered by women (e.g., education) have contributed to a substantial increase in the proportion of women in schools of engineering.[45]

Women, as a group, do not now possess the same degree of mathematical, spatial visualization and other aptitudes that males have (using currently accepted aptitude tests). Nevertheless, women constitute a large, untapped reservoir of engineering talent that may well help meet future demands for engineers, despite the projection of a marked decline in the numbers of young people of college age for the next two decades at least. Women, as well as minority groups, will undoubtedly change the character of the engineering profession in the future from its present white-male image.[45]

Changing Character of the Traditional Fields of Engineering

Some types of engineers have become a vanishing breed, not only because the industries they served have declined, but also because the characteristics of the industries themselves have changed. For example, this study projects a large increase in demand for mining engineers due to the energy crisis. Mining, however, has become increasingly mechanical because of the tremendous amount of machine technology now required to efficiently, safely and economically mine coal and other minerals. The engineering need of mines will be, in part, a need for mechanical engineers rather than the more traditional mining engineers.

Petroleum engineers, likewise, are less in demand since petroleum processes have become more chemical in character rather than being physical separations-related. Chemical engineers will undoubtedly fill a portion of the project demand for petroleum engineers. In addition, geologists may be replacing both mining and petroleum engineers due to the current emphasis on finding new deposits. The degree fields of mining and petroleum engineering will emphasize chemical, mechanical and geological coursework as a consequence.

Engineering a Protean Field

In sum, engineering responds to the same forces and imperatives that change society as a whole. A rapidly changing technological society of necessity means a rapidly changing engineering profession, because engineers are fundamental to the application of the knowledge being gained at a constantly increasing rate.

The Problem of Obsolescence

It is commonly said that an engineer's knowledge and skills become largely obsolete in five to 10 years in the face of the rapid growth of our technology. Historically, industry has simply discarded the obsolescent, older engineer or has refused to hire him/her, especially if he/she has had only narrow experience in previous positions.

The obvious implication is that regular, continued in-service education should be a high priority of the engineering profession and industry if trained engineering talent is not to be needlessly wasted.

Provision for such upgrading must be made explicit, since few employers typically allow time for such activity. Schools of engineering may well play a leading role here if demand continues to exceed supply.

It is also probable that current engineering curricula should be examined to see whether engineers could be more broadly trained to render them more flexible when the demand picture changes rapidly and leaves them unemployed, as occurred with aerospace engineers. Certainly, the current picture of the older engineer as relatively inflexible and unemployable, except in his/her own narrow work specialty, has had a catastrophic effect on enrollments in the schools of engineering despite continued demand.

The young and their parents are well aware of the firing of older engineers and of their difficulty in being hired elsewhere. They are well aware that government technological priorities change and make the aerospace engineer or other types of engineer prone to unemployment and retraining. It is quite possible that never again will engineering be as attractive as it was during the post-Sputnik era.

THE PROBLEM OF DATA

The U.S. census and related surveys are the principal sources of data on the general characteristics and numbers of engineers and scientists in the United States. The census, taken every 10 years, collects limited information on the entire population, though more detailed questionnaires are filled out by a random, 20 per cent sample of households.[61,62] In essence, the census tallies as engineers only those respondents who say they are engineers.

As a consequence, we find in the census data 14-year-old engineers, engineers with less than an 8th grade education, engineers who work 52 weeks a year and yet earn less than $3,000. Obviously, these findings are not compatible with the concept that engineering is a highly trained specialty requiring college level work and, ideally, a baccalaureate or higher degree.

Such anomalies in the census are explained by two factors at least. First, many employers hire individuals for positions which they label as "engineering" but which actually do not require the training or the skills of a baccalaureate degree-holding engineer. Some of these positions are simply holdovers from the past: railroad engineer. Other positions may be labeled to make them seem more prestigious than the pay would imply.

The second factor explaining the oddities of the census data on engineers is the tendency of many people to give their work a greater importance by giving it an important-sounding label. So, the janitor becomes a sanitary engineer, and the person who installs air conditioners calls himself/herself a cooling systems engineer.

In practice, these things make census data unsuitable as the basis for estimating the demand and supply of college-educated engineers, unless the data can be corrected somehow to reflect the number of college-trained engineers.

Even if the census data itself were valid, the proportion of baccalaureate and higher degree engineers in the total sample is so small as to allow substantial error. Fortunately, a detailed post-census survey of about 100,000 people reported in 1970 as scientists, engineers or technicians was undertaken in 1972 to obtain a more detailed picture of the age distribution and educational level of self-defined engineers.[54,68] This post-censal data made possible the projections of demand for baccalaureate degree engineers.

Norman Seltzer, of the National Science Foundation, is reported in the April 1975 edition (Vol. 12, No. 3) of Science, Engineering and Technical Manpower Comments, to have made an as-yet unpublished, detailed analysis of the 1972 post-censal survey to determine how many respondents could actually be identified as scientists or engineers. Under his criteria some one million persons from the 1970 census were identified as engineers by the post-censal survey.

Many of those so identified were listed in the 1970 census as scientists, managers, technicians, etc., while others identified in the 1970 census as engineers were not so classified by Seltzer. Of the one million engineers, 22 per cent were electrical engineers; 19 per cent were mechanical engineers; 14 per cent were civil engineers; and 45 per cent fell in some other field of engineering.

Seltzer is also reported as having found that, under his definition of engineer, nine per cent had no degree or only 1-4 years of college; two per cent had an associate degree; 67 per cent possessed the B.S. degree; 17 per cent had the master's degree; four per cent held the Ph.D. degree and one per cent held a degree in a field other than engineering.

Obviously, there is a great need for a standardized definition of who an engineer is, since findings now vary so widely from source to source.

Employment statistics of the U.S. Department of Labor, collected monthly by the Bureau of the Census from the Current Population Survey (CPS) sample, are another possible source of data. This data source is based upon a sample of about 52,500 housing units representing about 105,000 people. Unfortunately, little information on engineers can actually be obtained here because the number of engineers in the sample is so very small. Also, for this report's purposes, the need for data at the state level makes the employment sampling even less adequate.

In general, the most serious deficiencies in the data now available may be described as follows: (1) inconsistency of definition, (2) lack of coordination in collecting data, (3) excessive delay in publishing data, (4) data too gross and lacking in detail and (5) a lack of regular collection of data over a period of time.

"Engineer" is defined so loosely that seldom are two sets of statistics directly comparable. Educational statistics, for example, refer specifically to students or graduates of an engineering curriculum while manpower statistics include as an engineer anyone who describes himself/herself as such to a census enumerator or is called such by an employer. This lack of comparability seldom allows reliable, demand-versus-supply comparisons, e.g., relating such projections as the "average annual openings" of the U.S. Department of Labor to the actual or projected supply of engineering graduates.

In addition, the needed data may not become available until two or more years after it is collected. So, projections and studies are necessarily based upon old data and do not take into account the major economic and other changes that may have taken place since.

Furthermore, statistics from different sources are often unusable because of a failure to standardize categories. Educational statistics, for example, are often broken down into three degree levels and 20 specialized areas of engineering. Most census and other employment statistics, on the other hand, are typically broken down into 10 or fewer specialized fields of engineering; furthermore, they are not usually categorized by degree level. In too many instances, engineers are simply lumped into a "professional and technical" category that is far too broad to be useful.

Finally, since data on engineers is typically not collected on any regular basis, it is almost impossible to determine accurately whether the nation has a manpower shortage or surplus in any specific field at any given time. Projections in terms of "average annual openings" make no allowances for recessions, foreign crises, energy-sufficiency crash programs, etc. The absence of regularly collected data makes it difficult to monitor the effect or such events upon manpower demand and supply. Government assessments of engineering and scientific manpower have been carried out for only a period of years and then abandoned. Even when they were carried out, the data obtained were insufficiently detailed to show important trends. The researcher is therefore too often forced to be content with data that are relevant to only one particular point in time.

SOME NATIONAL PROJECTION STUDIES

A variety of efforts has been made to project the need for engineers into the 1980s. Space does not permit detailing them, but some of the more interesting efforts should be mentioned.

The U.S. Bureau of Labor Statistics regularly publishes projections of demand for various occupations listed in the U.S. Census. The methodology used is essentially the same as that used to generate the growth estimates for Pennsylvania in this study.

The basic method, outlined in Tomorrow's Manpower Needs,[56] uses a basic occupation by industry matrix for either the state or the nation. A variety of publications have given the results of the use of this methodology, most notably such publications as Occupational Manpower and Training Needs[69,71] and the Occupational Outlook for College Graduates[68,70] published by the U.S. Department of Labor, Bureau of Labor Statistics.

John Alden, executive secretary of the Engineering Manpower Commission of the Engineers Joint Council, has also attempted to project the demand for engineers and interface it with supply estimates.[1] He foresees a drop in supply through 1976-77, followed by a rise that never approaches the probable demand (nationally). He projects a drop in supply from about 39,000 graduates in 1972 to 27,500 in 1976-77, an upswing to possibly 34,500 by 1983; the range of probable demand is 50,000 to 69,000 by 1982.

One of the most impressive studies, in terms of detail, is that carried out by the manpower committee of the Institute of Electrical and Electronic Engineers in New York City.[32] The committee not only attempted to assess the need for electrical and electronic engineers but to give consideration to the probable need for other types of engineers.

An unusual and thought-provoking effort is that of Wallace R. Brode in an article "Manpower in Science and Engineering, Based on a Saturation Model," in the July 1971 issue of Science.[12] Brode, a member of the Scientific Manpower Commission of the American Association for the Advancement of Science, contends that only a limited portion of the college-age population (18-22) has the motivation and the ability to complete a scientific or engineering course. He points out that, despite a marked rise in the number of graduates from college, the rate of expansion in science and engineering was slowing down in the 1960s. Brode contends that the concept of saturation in the production of scientists is a fruitful one in assessing the possible limit to supply in a period of high demand. He pointed in 1971 that since 1960 the percentage of 22-year-olds graduating in science and engineering was essentially constant at 3.8 per cent of the college-age population and apparently represented a ceiling. Efforts to increase this percentage were ineffective, even when jobs were plentiful and salaries were attractive.

Brode sees a possible surplus of no more than 10 per cent of supply between 1968 and 1983, followed by a very real shortage after 1987 due to the plummeting birthrate. He says, "In about a quarter of a century, we are going to have essentially the same number of 22-year-olds from which to draw our scientists and engineers," as in 1970. In the meantime the population will continue to grow and add to needs, while continued technological and scientific expansion will further increase those needs.

Brode's findings are consistent with the analysis found in this study for Pennsylvania, i.e, demand greater than supply through the late 1970s, then a probable increasing need beyond 1983 which will deepen toward the end of the century.

A final study of considerable interest is reported by John K. Folger, Helen S. Astin and Alan E. Bayer in Human Resources and Higher Education, published by the Russell Sage Foundation.[29]

Aside from considering the shortage of engineers and projecting estimates of demand, the authors deal with mechanisms for redressing project imbalances. They point out that in the past, industry made up for the shortage of graduates chiefly by "quality substitution." By this they mean the employment of less well qualified persons when qualified engineers are not available. They foresee a long-range lack of qualified engineers unless efforts are made to increase the proportion of entering engineering students who obtain the B.S. degree and unless efforts are made to increase the proportion choosing engineering as their major. This will obviously not be an easy task if Brode[12] is right in his saturation concept. Populations relatively untapped in the past, such as women and minorities, are potential reservoirs of supply, although the authors do not make this point.

All of these projections seem to agree that a shortage will develop during the late 70s and early 80s and that it may continue if there is a continued decline in the birth rate. None of these studies were made following the energy crisis. They do not reflect the increased demand foreseen by the National Planning Association. The NPA sees the 1985 demand being double that of 1970, if the U.S. dependency on foreign sources of energy amounts to nine per cent of the total need.

The NPA foresees the largest energy-related increase in terms of demand to be for electrical engineers, followed by chemical and mechanical engineers. The response is seen as absorbing 20 to 30 per cent of all engineers produced between 1975 and 1980 and more than 30 per cent by 1985 to meet the needs of energy-related industries alone. These industries now employ only about 10 per cent of all engineers.

Obviously, the situation projected by the studies cited earlier will worsen if the United States is forced to make the kind of response foreseen by Gutmanis[30] in his study for the National Planning Association. Pennsylvania will, of course, be similarly affected and have a more serious shortage than would otherwise be the case.

THE PENNSYLVANIA ENGINEER

Despite the inherent limitations of existing data with regard to the assessment of the supply and demand for college-trained engineers, it may be of interest to present some of the typical tabular material available through such sources as the U.S. Bureau of the Census and the National Engineers Register.

Tables 1 and 2 illustrate the nature of the census data available for Pennsylvania with regard to engineers. As can be seen, the number of individuals listed as engineers by the census enumerators for 1960 and 1970 is substantial; and there is no way to separate the number who are college trained from those who are not college trained. Also, the published census figures are not finely detailed according to age and sex; this makes mortality, disability and retirement difficult to estimate. If the census data were ideally broken down, we would need, for each engineering speciality, details on educational level by sex-by-age.

Table 1

U.S. Census Estimates of the Number of Experienced Engineers in the Labor Force as of 1960[a]

Category	1960 Census Employed[c]			1960 Census Experienced Unemployed[d]			1960 Census Experienced Civilian Labor Force[e]		
	Male	Female	Total	Male	Female	Total	Male	Female	Total
Aeronautical	714	9	723	29	0	29	743	9	1,775
Chemical	3,081	21	3,102	14	0	14	3,095	21	3,648
Civil	7,665	48	7,713	270	5	275	7,935	53	8,281
Electrical[b]	11,071	110	11,181	58	0	58	11,129	110	14,675
Industrial	8,384	117	8,501	112	0	112	8,496	117	11,278
Mechanical	9,591	28	9,619	128	0	128	9,719	28	10,297
Metallurgical[b]	1,438	-	1,438	17	-	17	1,455	-	2,052
Mining	370	-	370	20	-	20	390	-	314
Petroleum	365	-	365	17	-	17	382	-	100
Sales	4,743	13	4,756	62	0	62	4,805	13	4,025
Engineers, N.E.C.	4,227	44	4,271	34	0	34	4,261	44	11,649
All Engineers	51,649	390	52,039	761	5	766	52,410	395	52,805

[a] Data from Table 170 of 1960 Census of Population: Detailed Characterisics--Pennsylvania

[b] Some categories are abbreviated, i.e., aeronautical and astronautical, electrical and electronic, metallurgical and materials.

[c] Experienced labor force, employed in 1960, 14 years or older from Table 170 of note "a".

[d] Difference between total experienced labor force, 14 years and older, and those employed.

[e] Experienced civilian labor force statistics for 14 years and older from Table 170 in note "a" above. Does not include retired, disabled, etc.; only those desiring employment.

Table 2

U.S. Census Estimates of the Number of Experienced Engineers in the Labor Force as of 1970[a]

Category	1970 Census Employed[c]			1970 Census Experienced Unemployed[d]			1970 Census Experienced Civilian Labor Force[e]		
	Male	Female	Total	Male	Female	Total	Male	Female	Total
Aeronautical	1,624	24	1,648	127	0	127	1,751	24	1,775
Chemical	3,602	37	3,639	9	0	9	3,611	37	3,648
Civil	8,103	88	8,191	90	0	90	8,193	88	8,281
Electrical[b]	14,236	206	14,442	228	5	233	14,464	211	14,675
Industrial	10,798	287	11,085	190	3	193	10,988	290	11,278
Mechanical	10,091	96	10,187	110	0	110	10,201	96	10,297
Metallurgical[b]	2,028	9	2,037	15	0	15	2,043	9	2,052
Mining	314	-	314	0	-	0	314	-	314
Petroleum	87	-	87	13	-	13	100	-	100
Sales	3,994	13	4,007	18	0	18	4,012	13	4,025
Engineers, N.E.C.	11,374	122	11,496	153	0	153	11,527	122	11,649
All Engineers	66,251	882	67,133	953	8	961	67,204	890	68,094

[a] Data from Table 170 of 1970 Census of Population: Detailed Characteristics--Pennsylvania.

[b] Some categories are abbreviated, i.e., aeronautical and astronautical, electrical and electronic, metallurgical and materials.

[c] Experienced labor force, employed in 1970, 14 years or older from Table 170 of note "a".

[d] Difference between total experienced labor force, 14 years and older, and those employed.

[e] Experienced civilian labor force statistics for 14 years and older from Table 170 in note "a" above. Does not include retired, disabled, etc.; only those desiring employment.

The census data is further limited by the fact that many trained engineers are no longer enumerated as engineers but are placed in another, usually managerial, classification. Nevertheless, these engineers die, retire or become disabled and are replaced, often by other engineers. Therefore, they represent a hidden demand that is typically not accounted for in supply-demand studies. The present study is no exception.

Nevertheless, some data of interest can be gleaned from census tables. For example, Table 3 indicates the change in the unemployment picture for engineers in Pennsylvania from 1960 to 1970. As can be seen, there was a marked increase in unemployment for astro-aeronautical, electrical, industrial and petroleum engineers. On the other hand unemployment among chemical, civil, mechanical, metallurgical, mining and sales engineers went down markedly. Obviously, these changes can be traced to less federal funding of aerospace projects, the marked increase in buildings and construction during this period, the relatively small output of mining engineers from the colleges, the development of chemical industries within the state, the increasing dependence on foreign oil and diminishing domestic supplies, etc.

The picture has changed radically since 1970 due to the energy crisis and the inflation/recession-induced slowdown in construction. However, the so-called unemployment has involved engineers without degrees.[1]

The Comm-Bacc study of William Toombs[57] and the publications of the College Placement Council have consistently indicated the superior employment position of the engineering graduate over all others. Only graduates in health care and computer sciences have experienced lower rates of unemployment.

Unfortunately, publicity in the mass media concerning the negative trend toward the over-45, systems-trained aerospace engineer aggravated the negative trend toward students avoiding science and engineering curricula. This trend was recently (fall 1974) revised with a 20 per cent rise in college freshmen over 1973, as reported by the Engineering Manpower Commission of the Engineers Joint Council in the April 28, 1974 edition of The Chronicle of Higher Education.[24] This reversal of a 10-year trend in declining enrollments, beginning in 1963, probably resulted from an increasing awareness of a demand for engineers and a growing surplus of degree recipients in other areas, such as teaching. In other words, the students are going where the likelihood of finding work after graduation is greatest.

Table 4 contains data on engineers in Pennsylvania and the nation in terms of the curricula in which they received their B.S. degree. This study, American Engineering Manpower 1969: Statistics from the 1969 National Engineers Register, was the most detailed of the National Register studies carried out over a period of years.[3,25] Unfortunately, data for other years[2] was much less detailed; and in recent years obtaining a register of engineers was abandoned by the federal government and left in the hands of the Engineers Joint Council Manpower Commission, which admittedly has limited resources.

The register data are not comparable to census data; nor are they necessarily a complete and accurate accounting of engineers, since the National Engineers Register is based upon a sampling of members of professional engineering societies. Therefore, any engineers who are not members or who do not possess a degree are likely to be eliminated.

Table 3

Percentage of Experienced Engineering Labor Force Unemployed as of 1960 and 1970[a]

Category[b]	Males		Females		Total	
	1960	1970	1960	1970	1960	1970
Aeronautical	3.90	7.25	0.00	0.00	3.86	7.15
Chemical	0.45	0.25	0.00	0.00	0.45	0.25
Civil	3.40	1.10	9.43	0.00	3.46	1.09
Electrical	0.52	1.58	0.00	2.37	0.52	1.59
Industrial	1.32	1.73	0.00	1.03	1.30	1.71
Mechanical	1.32	1.08	0.00	0.00	1.31	1.07
Metallurgical	1.17	0.73	-	0.00	1.17	0.73
Mining	5.13	0.00	-	-	5.13	0.00
Petroleum	4.45	13.00	-	-	4.45	13.00
Sales	1.29	0.45	0.00	0.00	1.29	0.45
Engineers, n.e.c.	0.80	1.33	0.00	0.00	0.79	1.31
All Engineers	1.45	1.42	1.27	0.90	1.45	1.41

[a] Data derived from Tables 1 and 2 of this report by dividing the estimated number of unemployed by the census estimates of the number of experienced engineers in the labor force.

[b] Some categories are abbreviated, i.e., aeronautical and astronautical, electrical and electronic, metallurgical and materials.

Table 4

An Analysis of the Distribution of Pennsylvania and U.S. Engineers by Curricula Based Upon the National Registry of Engineers for 1969[a]

Curricula	Pennsylvania	Amended United States[b]	Pa. Per Cent Distribution	National Per Cent Distribution	Pa. Per Cent of National
*Aerospace	500	11,800	2.43	4.24	4.24
Chemical	2,300	28,200	11.16	10.14	8.16
*Civil	2,800	48,200	13.59	17.33	5.81
Electrical	4,900	62,800	23.79	22.57	7.80
General	1,500	20,400	7.28	7.33	7.35
Mechanical	4,700	60,500	22.82	21.75	7.77
*Metallurgical	1,700	10,300	8.25	3.70	16.50
*Mineral	700	13,800	3.40	4.96	5.07
Other	1,500	22,200	7.28	7.98	6.76
Not Reported	100	1,500	-	-	6.67
Total Curricula Reported	20,600	278,200	100.00	100.00	7.40
B.S. Degrees Reported	20,700	279,700	91.19[c]	90.87[c]	7.40
No B.S. Degrees Reported	2,000	28,100	8.81[c]	9.13[c]	7.12
Total	22,700	307,800	100.00	100.00	7.37

*Curricula where Pennsylvania differs substantially from the nation in terms of relative representation, i.e., fewer aerospace, civil and mineral engineering graduates employed here but more metallurgical.

[a] Data from American Engineering Manpower 1969: Statistics from the 1969 National Engineers Register published by the Engineering Manpower Commission of Engineers Joint Council, New York, November 1971, p. 67.

[b] The figures given by the Engineering Manpower Commission for the United States did not add up to the total given, i.e., totals amended to read 307,800 instead of 308,000 and 279,700 instead of 279,800.

[c] Percentages here represent the degree versus no degree representation in this sampling of the members of professional engineering societies.

Table 3

Percentage of Experienced Engineering Labor Force
Unemployed as of 1960 and 1970[a]

Category[b]	Males		Females		Total	
	1960	1970	1960	1970	1960	1970
Aeronautical	3.90	7.25	0.00	0.00	3.86	7.15
Chemical	0.45	0.25	0.00	0.00	0.45	0.25
Civil	3.40	1.10	9.43	0.00	3.46	1.09
Electrical	0.52	1.58	0.00	2.37	0.52	1.59
Industrial	1.32	1.73	0.00	1.03	1.30	1.71
Mechanical	1.32	1.08	0.00	0.00	1.31	1.07
Metallurgical	1.17	0.73	-	0.00	1.17	0.73
Mining	5.13	0.00	-	-	5.13	0.00
Petroleum	4.45	13.00	-	-	4.45	13.00
Sales	1.29	0.45	0.00	0.00	1.29	0.45
Engineers, n.e.c.	0.80	1.33	0.00	0.00	0.79	1.31
All Engineers	1.45	1.42	1.27	0.90	1.45	1.41

[a] Data derived from Tables 1 and 2 of this report by dividing the estimated number of unemployed by the census estimates of the number of experienced engineers in the labor force.

[b] Some categories are abbreviated, i.e., aeronautical and astronautical, electrical and electronic, metallurgical and materials.

Table 4

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Curricula	Pennsylvania	Amended United States[b]	Pa. Per Cent Distribution	National Per Cent Distribution	Pa. Per Cent of National
*Aerospace	500	11,800	2.43	4.24	4.24
Chemical	2,300	28,200	11.16	10.14	8.16
*Civil	2,800	48,200	13.59	17.33	5.81
Electrical	4,900	62,800	23.79	22.57	7.80
General	1,500	20,400	7.28	7.33	7.35
Mechanical	4,700	60,500	22.82	21.75	7.77
*Metallurgical	1,700	10,300	8.25	3.70	16.50
*Mineral	700	13,800	3.40	4.96	5.07
Other	1,500	22,200	7.28	7.98	6.76
Not Reported	100	1,500	-	-	6.67
Total Curricula Reported	20,600	278,200	100.00	100.00	7.40
B.S. Degrees Reported	20,700	279,700	91.19[c]	90.87[c]	7.40
No B.S. Degrees Reported	2,000	28,100	8.81[c]	9.13[c]	7.12
Total	22,700	307,800	100.00	100.00	7.37

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*Curricula where Pennsylvania differs substantially from the nation in terms of relative representation, i.e., fewer aerospace, civil and mineral engineering graduates employed here but more metallurgical.

[a] Data from *American Engineering Manpower 1969*: *Statistics from the 1969 National Engineers Register* published by the Engineering Manpower Commission of Engineers Joint Council, New York, November 1971, p. 67.

[b] The figures given by the Engineering Manpower Commission for the United States did not add up to the total given, i.e., totals amended to read 307,800 instead of 308,000 and 279,700 instead of 279,800.

[c] Percentages here represent the degree versus no degree representation in this sampling of the members of professional engineering societies.

Table 4 is of interest because it indicates that Pennsylvania has more engineers, proportionately, than one would expect based on its six per cent share of the national population. Pennsylvania has over seven per cent of the nation's degree-holding engineers, if the National Register sample can be considered representative.

With regard to the proportion graduating in each curriculum area, Pennsylvania has a smaller proportion in the aerospace, civil, mineral and "other" curricula than the nation as a whole but a larger proportion than the nation for chemical, electrical, mechanical and metallurgical engineering and virtually identical proportions (seven per cent) for graduates of the general engineering curricula. Particularly noteworthy is the very high proportion of metallurgical engineers (8.25 per cent as compared with 3.70 per cent for the nation). The markedly lower proportion of aerospace curricula engineers is not surprising since there is relatively little aerospace industry in Pennsylvania. Space-related activities may well increase in the future counterbalancing the present air frame oriented emphasis.

Although precise degree-by-age statistics for Pennsylvania are not readily available, some idea of the age distribution of different degree levels for various engineering specialties in the nation as a whole can be gleaned from Table 5. If we assume that a similar pattern holds for Pennsylvania, it is easy to see that engineers in the various specialties differ considerably as to their age distribution and that the degree level attained also affects the age distribution.[67]

The data in Table 5 suggest that combining degree and nondegree engineers results in a higher median age and, therefore, higher mortality and retirement estimates than would be found for degree-holding engineers alone. It further suggests that the use of an age distribution for all engineers combined tends to underestimate mortality and retirements for degree-holding mining and petroleum engineers and, especially, chemical engineers. At the same time it overestimates somewhat the rates for electrical/electronic engineers.

How tenable the assumption that Pennsylvania's distribution is comparable to the nation's can be tested to some degree by comparing the findings of Table 5 with the Pennsylvania figures taken from the 1969 National Engineers Register which emphasized degree-holding engineers who are members of professional engineering societies.[25] Table 6 presents this comparison.

As can be seen, an assumption of an exact, one-to-one relationship between national estimates and Pennsylvania figures from a different group is not completely tenable. However, there is a closer correspondence to be noted for the older age groups, possibly because the older ones are more likely to become active members of professional societies. If true, this would render the two samples more comparable and suggest that the assumption that national data-on-age-by-degree distributions can reasonably be applied to Pennsylvania engineering data.

Table 5

Age Distribution (Per Cent) and Median Age of Engineers in the 1970 Census Based Upon a Post-Censal Sample[a]

Type	Degree	Age					Median Age[b] Years
		Under 25	25-34	35-44	45-54	55 plus	
		(%)	(%)	(%)	(%)	(%)	
Aero/Astro	B.S. plus	1.96	29.43	34.24	25.98	8.39	39.94
	Associate	4.92	17.81	42.62	29.96	4.69	40.90
	None	1.07	14.60	29.28	35.65	19.40	45.92
	Total	1.81	24.70	33.12	28.93	11.44	41.59
Chemical	B.S. plus	2.59	33.85	26.13	26.72	10.71	49.69
	Associate	4.59	30.95	46.60	13.27	4.59	37.60
	None	3.41	19.78	21.62	31.53	23.66	46.15
	Total	2.72	31.91	25.75	27.22	12.40	40.47
Civil	B.S. plus	1.72	28.94	30.19	21.98	17.17	40.91
	Associate	4.49	49.29	26.75	15.92	3.55	33.73
	None	4.47	16.60	24.78	26.97	27.18	46.04
	Total	2.80	25.22	28.12	23.57	20.29	42.32
Elec/Electronic	B.S. plus	2.58	33.94	34.82	20.16	8.50	38.37
	Associate	5.88	39.32	38.59	14.60	1.61	35.74
	None	1.63	21.78	27.34	30.50	18.75	44.23
	Total	2.43	30.37	32.64	23.15	11.41	39.77
Industrial	B.S. plus	1.74	30.78	30.86	24.63	11.99	40.16
	Associate	3.52	41.49	31.35	15.43	8.21	36.09
	None	1.96	16.45	24.60	33.40	23.59	46.59
	Total	1.91	24.67	28.03	28.27	17.12	42.85
Mechanical	B.S. plus	1.72	32.01	28.04	27.29	10.94	40.30
	Associate	2.89	30.79	38.05	21.86	6.41	38.79
	None	2.97	12.79	23.85	32.67	27.72	47.68
	Total	2.20	25.16	26.89	29.02	16.73	42.92
Metals/Materials	B.S. plus	0.96	27.25	31.27	24.91	15.61	41.47
	Associate	8.52	59.62	15.77	16.09	0.00	31.46
	None	2.74	13.66	25.62	32.13	25.85	46.98
	Total	1.57	24.45	29.51	26.57	17.90	42.63

Table 5

(continued)

Type	Degree	Age Under 25 (%)	 25-34 (%)	 35-44 (%)	 45-54 (%)	 55 plus (%)	Median Age[b] Years
Mining/Petrol	B.S. plus	2.17	24.88	29.36	26.99	16.60	42.32
	Associate	0.00	44.85	37.50	17.65	0.00	35.87
	None	4.23	10.03	32.99	23.90	28.85	45.65
	Total	2.55	22.16	30.14	26.31	18.84	42.89
Sales	B.S. plus	1.04	27.01	30.89	28.32	12.74	41.61
	Associate	0.00	41.43	37.53	12.44	8.60	36.78
	None	0.70	18.78	24.31	29.95	26.26	46.57
	Total	0.86	24.00	28.33	28.50	18.31	43.37
N.E.C./Teachers	B.S. plus	1.86	30.31	29.41	25.02	13.40	40.56
	Associate	6.24	43.04	34.83	11.57	4.32	34.71
	None	1.43	20.99	27.22	27.51	22.85	44.63
	Total	1.88	27.61	28.87	25.34	16.29	41.60
All Engineers	B.S. plus	1.92	31.20	30.99	24.06	11.83	39.95
	Associate	4.72	39.47	35.27	16.08	4.46	36.15
	None	2.16	17.84	25.77	30.60	23.63	45.88
	Total	2.11	26.88	29.34	26.03	15.64	41.66

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[a] Percentages derived from Table 1 of "Engineers and Scientists in the 1970 Experienced Civilian Labor Force, By Age, Highest Degree Held and Sex in 1972," found in Characteristics of Persons in Engineering and Scientific Occupations: 1972. Technical Paper No. 33, published by the U.S. Bureau of the Census, 1974.

[b] Based upon the percentage values in this table and assumes an equal age distribution over all values in a given age class, such as 35-44.

Table 6

Comparative Percentage Distributions by Age Group for National and Pennsylvania Engineers

Age Group	National Census[a]				National Register (Pa.)[b]	
	Total	No Degree	Associate Degree	B.S. Plus	All Engineers	
	(%)	(%)	(%)	(%)	(%)	(#)
Under 25	2.11	2.16	4.72	1.92	1.83	400
25-34	26.88	17.84	39.47	31.20	24.29	5,300
35-44	29.34	25.77	35.27	30.99	31.62	6,900
45-54	26.03	30.60	16.08	24.06	27.50	6,000
55+	15.64	23.63	4.46	11.83	14.77	3,224
Total	100.00	100.00	100.00	100.00	100.00	21,824
No Report	-	-	-	-	-	300

[a] See Table 5

[b] Derived from American Engineering Manpower 1969: Statistics from the 1969 National Engineers Register, Engineering Manpower Commission, Engineers Joint Council, New York, 1971.

[c] The figures have been modified to delete some 676 retired engineers in order to make the figures more comparable to census data on work force engineers.

It should also be noted that while the 1970 census figures of Table 2 list the total of experienced engineers in the labor force as 68,094, the number indicated in the National Register of 1969 for Pennsylvania is 22,000. This indicates a vast discrepancy between census figures and other available figures based upon licensed engineers, engineers who are in professional societies, etc.

Finally, it may be of interest to look at some available data on (1) the type of Pennsylvania industries in which Pennsylvania's engineers (census count) were employed in 1970 and (2) their projected employment in 1980. Table 7 summarizes these findings. It should be pointed out that the projections for 1980 were made prior to the energy crisis and that certain industries (marked with an asterisk) may well have a larger share than shown if the response to the energy crisis is directed at increased self-sufficiency.

As Table 7 illustrates, 85 per cent of all aeronautical engineers in Pennsylvania in 1970 were in the Durable Goods Manufacture Sector, while 78 per cent were in Aircraft and Aircraft Parts, a subcategory of Durable Goods. That is, they are involved in the manufacture of aircraft or aircraft parts in plants such as Piper Aircraft, Sikorsky, etc.

Four per cent are apparently involved in services (consulting, etc.) while eight per cent are in government work, primarily federal government positions related to aircraft.

Table 7

A Summary of Pennsylvania Employment Patterns by Industry Sector for Engineering Specialties[a]

1970 Percentage[b]	1980 Percentage[b]	Industry Sector
I. Astro-Aeronautical Engineering		
85	88	Durable Goods Manufacture
78	85	Aircraft and Parts Manufacture
7	4	Services
8	8	Government
7	8	Federal Government
II. Chemical Engineers		
84	82	Manufacturing
29	25	Durable Goods Manufacture
5	5	Stone, Clay and Glass Products
9	10	Primary Metal Industries
6	7	Blast Furnaces and Steel Works
11	8*[c]	Machinery, Electrical and Nonelectrical
55	57	Nondurable Goods Manufacture
36	39	Chemicals and Allied Products
13	13	Industrial Chemicals
15	14	Plastics and Synthetics
13	12*	Petroleum and Coal Products
7	6	Services
5	5	Engineering and Architectural Services
8	12	Other Industry Sectors Combined
III. Civil Engineering		
43	40	Construction
6	8	General Building Construction
34	32*	General Contracting
15	11	Manufacturing
12	9	Durable Goods Manufacture
8	7*	Transportation and Public Utilities
6	5	Communications, Utilities and Sanitary
21	31	Engineering and Architectural Services
7	7	Government (Federal, State and Local)
6	4	Other Industry Sectors Combined
IV. Electrical and Electronic Engineering		
59	58	Manufacturing
57	56	Durable Goods Manufacture
5	6*	Nonelectrical Machinery
40	38*	Electrical Machinery--Computers
2	2	Nondurable Goods Manufacture
21	20*	Transportation and Other Public Utilities
11	11	Communications
9	9	Telephone
9	8	Utilities and Sanitary Electric Power

Table 7

(continued)

1970 Percentage[b]	1980 Percentage[b]	Industry Sector
IV. Electrical and Electronic Engineering (continued)		
9	12	Services
6	7	Professional and Related Services
6	6	Engineering and Architectural Services
5	6	Government
5	5	Federal Government
6	4	Other Industry Sectors Combined
V. Industrial Engineering		
78	76	Manufacturing
64	65	Durable Goods Manfacture
15	11	Primary Metal Industries
7	7	Fabricated Metal Industries
19	12*	Machinery, Nonelectrical
16	18*	Machinery, Electrical
7	7*	Transportation Equipment
4	5	Professional and Scientific Equipment
14	12*	Nondurable Goods Manufacture (Textiles, (Paper Products, Chemical and Allied Products, Petroleum and Coal Products, Rubber)
8	9	Services
5	6	Miscellaneous Business Services
4	5	Business Management
5	5	Government (Primarily Federal)
9	10*	Other Industry Sectors Combined (Mining, Construction, Transportation, Communications and Utilities, Wholesale and Retail Trade, Professional and Related Services)
VI. Mechanical Engineering		
71	66	Manufacturing
63	57	Durable Goods Manufacture
7	7	Primary Metals Manufacture
7	5	Fabricated Metals Manufacture
21	17*	Machinery
9	11	Transportation Equipment (Auto, Ship, Air and Rail)
8	9	Nondurable Goods
7	8*	Transportation and Public Utilities
4	5	Utilities and Sanitary
11	14	Services (Professional, Business and Commercial R & D, Some Medical and Health)

Table 7

(continued)

1970 Percentage[b]	1980 Percentage[b]	Industry Sector
VI. Mechanical Engineering (continued)		
7	10	Professional and Related
6	9	Engineering and Architectural Services
5	5	Government (Primarily Federal)
6	7	Other Industry Sectors Combined
VII. Metallurgical and Materials Engineering		
89	85	Manufacturing
88	84	Durable Goods Manufacture
68	62	Primary Metals Industries
42	37	Blast Furnace, Steel Works
8	7	Other Steel
8	8	Primary Aluminum
10	10	Primary Nonferrous
5	6	Fabricated Metals
4	5	Machinery and Parts
8	9	Electrical Machinery
7	9	Services
4	7	Commercial R & D
4	6	Other Industry Sectors Combined
VIII. Mining Engineering		
52	62	Mining
40	57*	Coal Mining
11	5	Durable Goods Manufacture (Primarily Stone, Clay and Glass in 1980, less Primary Metals)
10	15	Services (Primarily Architectural and Engineering Services)
24	15	Government
10	4	Federal Government
14	11	State Government
3	3	Other Industry Sectors Combined
IX. Petroleum Engineering		
23	24*	Crude Petroleum and Natural Gas
7	15	Durable Goods Manufacture (Petroleum Products)
40	34*	Nondurable Goods Manufacture (Petroleum Products and Refining of Petroleum)
23	26*	Gas, Steam, Electric Supply Systems
7	1	Other Industry Sectors Combined

Table 7

(continued)

1970 Percentage[b]	1980 Percentage[b]	Industry Sector
X. Sales Engineering		
50	39	Manufacture
46	34	Durable Goods
16	8	Nonelectrical Machinery
12	12	Electrical Machinery
11	10	Primary Metals, Stone, Clay and Glass, Fabricated Metals, Combined
5	5	Nondurable Goods (Primarily Chemical and Allied Products or Rubber
51	50	Wholesale and Retail Trade
37	46	Wholesale Trade
7	8	Electrical Goods
17	24	Machinery Equipment and Supply
8	8	Miscellaneous Wholesale (primarily Metals and Minerals, Petroleum Products, Lumber and Construction Materials)
6	8	Construction (including Engineering and Architectural Services)
3	3	Other Industrial Sectors Combined
XI. Other Engineering Specialties Combined		
60	57	Manufacturing
51	50	Durable Goods Manufacture
9	6	Stone, Clay, Glass and Primary Metals
6	5	Fabricated Metal Products
15	17*	Machinery, except Electrical
11	12*	Electrical Machinery (including Computers)
6	7	Professional and Scientific Equipment (Scientific Instruments including Health or Optical)
9	7	Nondurable Goods Manufacture (Food, Paper, Chemicals, Petroleum, Coal, Rubber and Miscellaneous Plastics)
23	28	Services
4	5	Miscellaneous Business Services (Primarily Business Management, Commercial R & D, Computer Programming, Medical and Other Health Services)
11	17	Engineering and Architectural Services
17	15*	Other Industry Sectors Combined (Agriculture, Construction, Transportation, Public Utilities, Wholesale and Retail Trade, especially Machinery, Finance and Real Estate and Government)

Table 7
(continued)

FOOTNOTES

[a] Taken from Pennsylvania Occupations by Industry Matrices for 1970 and 1980 as developed by the Bureau of Labor Statistics using Method B of Tomorrow's Manpower Needs. The 1980 matrix does not include the impact of the energy crisis.

[b] The percentage figures below may be interpreted as the proportion of all Pennsylvania engineers (census) of this specialty found in that particular sector of industry.

[c] Asterisk indicates that this may be an underestimate since the energy crisis will affect this sector to some degree.

THE PROBLEM OF AN ENGINEERING MANPOWER MODEL

A projection of need for any occupation or profession cannot be haphazard. What is sought is a reasoned estimate of future need based upon a defensible rationale. The basis for such estimates should be well defined; and the best way of making the process explicable and clearly rational is through the use of a manpower model that specifies, by implication, the methodology to be used and the nature of the data to be sought. This section attempts to summarize the generalized model and rationale behind the projections in the present study.

The generalized model may be expressed by the equation:

Need - Demand = Supply

Where

Demand = Withdrawals + Growth
Withdrawal = Deaths + Retirements + Disability + Job Mobility (Out-migration) + change to Inactive Status
Supply = Terminal degree recipient output from Pennsylvania schools multiplied by the State holding rate + In-migration + Re-entry into the profession

The above model was useful because it did not require that the data come from a given source and it was open as to the method used in projecting growth, i.e., correlation, eyeballing of historical data, federal or other percentage growth estimates for the nation as a whole, the Bureau of Labor Statistics methodology used here, etc. Also the model did not require that data be obtained for every variable to be useful.

This point regarding the possible lack of data is important. Though an adequate data base is essential, it is also the most difficult problem facing an individual working on manpower projections, particularly with regard to data on the state or local level.

Thoughtful analyses of the problems in projecting engineering manpower are available; and they make it clear that the state of the art is still relatively primitive. They show that projections can vary widely, depending upon the methodological base and attendant assumptions.[1,7,9,14,27,29,54,58] Nevertheless, once a model or projection method is selected, the basic problem the researcher has to deal with is getting accurate data that can be considered as comparable over a period of time.

State and federal governments and other institutions collect and compile data solely on the basis of their current needs and often discard it when it is no longer current. When the needed data is collected, it is then frequently archived rather than made readily accessible on magnetic tape, etc. This, in turn, makes the analysis of historic trends difficult and the compilation of needed data much too time-consuming or expensive to readily undertake. In engineering, the situation is further compounded by a lack of agreement as to what constitutes an engineer and by a lack of standardization with regards to engineering categories.

The data used in this study came from a variety of sources and are, therefore, subject to the above limitations. As a consequence, developing estimates of the variables needed for the model has also required a variety of additional assumptions designed to permit derivation of needed data.

ENGINEERING DEMAND IN PENNSYLVANIA

As indicated by the manpower model described earlier, demand is a combination of (1) variables such as withdrawals due to death, retirement and out-migration, and (2) growth of the number of available openings. Of the two, growth is by far the most difficult to estimate, although accurate figures on migration for a given occupation are not easily obtained.

Problem of Choice of Method

The difficulty with estimating future demand due to growth lies in the fact that the growth of a given occupation depends on a large number of factors which are also hard to project: population growth, economic growth, technological change and federal research funding. Fortunately the federal government has developed a methodology which can be used with occupation-by-industry matrices derived from census or other available data. The methodology itself is described in the publication, *Tomorrow's Manpower Needs: National Manpower Projections and a Guide to Their Use as a Tool in Developing State and Area Manpower Projections*, Vols. I-IV, published by the Bureau of Employment Security, U.S. Department of Labor and Industry.[56]

The projections of growth for engineers as a whole and for the various subspecialties in this report are a result of a modified version of Method B described in the above publication. These projections were carried out for Pennsylvania and Maine by the U.S. Bureau of Labor Statistics. Allocations made are based upon an unpublished detailed survey of the nonrespondent population. The projections to 1980 assume the same nonrespondent distribution as in 1970 and are shown in Table 8.

Table 8

Projected 1970 to 1980 Change in Pennsylvania's Engineering Employment as Computed by the Bureau of Labor Statistics[a]

Types of Engineer	1970 Census[b]	1980 Projections[c]	1970 Per Cent Distribution	Projected 1980 Per Cent Distribution	1970-80 Numerical Percentage Change
Aero-Astronautical	1,500	1,800	2.04	2.12	20.00
Chemical	3,918	3,756	5.33	4.42	- 4.13
Civil	9,288	10,997	12.63	12.93	18.40
Electrical	15,178	17,849	20.63	20.99	17.60
Industrial	12,467	15,207	16.95	17.88	21.98
Mechanical	11,208	11,828	15.24	13.91	5.53
Metallurgical	2,228	2,370	3.03	2.79	6.37
Mining	330	334	0.45	0.39	1.21
Petroleum	88	99	0.12	0.12	12.50
Sales	4,784	4,705	6.50	5.53	- 1.65
Other, n.e.c.	12,565	16,104	17.08	18.93	28.16
All Engineers	73,554	85,049	100.00	100.00	15.63

[a] Data taken from computer printouts supplied by Frederick L. Bauer, associate assistant regional director for program and analysis, Bureau of Labor Statistics, Mideast Regional Office, U.S. Department of Labor and consisting of 1970 and 1980 Iterated Pennsylvania Matrices computed according to a modification of Method B detailed in the publication Tomorrow's Manpower Needs.

[b] These figures will not agree with published census figures due to the allocation process used by BLS. This process represents a correction of the 1970 census data through allocation of nonrespondents. This allocation was based upon a detailed unpublished survey of the nonrespondent population.

[c] The 1980 projections assume a comparable nonrespondent allocation pattern to that of 1970, i.e., growth estimates applied to the allocated 1970 figures.

All projections were carried out before the Arab oil embargo and subsequent energy crisis, with its attendant impact on the U.S. economy. We must, therefore, assume in Table 8 that the present recession constitutes a relatively short-term phenomenon and that these projections will, in fact, be valid over the long term. It is evident that a further attempt will have to be made to estimate the impact, between 1970 and 1980, of our probable response to the energy crisis in terms of engineering demand.[30,39]

Assumptions Made Relative to Growth

The assumptions made by the U.S. Bureau of Labor Statistics in developing the projections of Table 8 may be described as follows:

1. A relatively high employment level.
2. Area changes will follow the patterns developed by the bureau.

3. The rate and change of economic growth will not be significantly affected by an unforeseen major event.
4. Economic and social patterns and relationships will continue to change at about the same rate as in the recent past.
5. Scientific and technological advances of recent years will continue at about the same rate.
6. Defense expenditures will remain at "cold war" levels.

The figures in columns 1 and 2 of Table 8 actually represent a count of workers by place of residence, i.e., one job per worker, with those holding more than one job being classified in their primary occupations. The figures are probably lower than the true value because some workers undoubtedly commute. There is no current data to tell us whether the net commutation favors the state. These estimates must then be accepted as close to the true value (Table 8).

As also seen in Table 8, on the basis of historical patterns prior to 1970 and upon projected trends that are themselves based upon the growth assumptions cited above, the greatest growth would seem to be in aero-astronautical, civil, electrical, industrial, petroleum and "other" engineering categories (nuclear, biomedical, etc.). Later, of course, these projections will have to be modified to reflect the response to the energy crisis.

While the overall projection of a 15.63 per cent increase in the number of employed engineers between 1970 and 1980 agrees with other estimates for Pennsylvania[50] and with tentative projections by the National Planning Association, it is obvious that the growth of the 1960s is not being duplicated in the 1970s to date. The reduction of the aerospace effort in the late 1960s undoubtedly reduced the need for aeronautical engineers. Yet, in Table 8 there is a marked growth in aeronautical engineering as projected for Pennsylvania. This finding certainly requires some analysis.

Pennsylvania itself has been little involved in the aerospace program. Therefore, Pennsylvania's engineers have not been as greatly affected by the reduction in federal funding as engineers in general. Though the reduction of the Piper Aircraft staff in the late 1960s is reflected in Table 8 projections, Piper was not a major employer that would markedly affect the projections. Of more concern, perhaps, is the impact of the energy crisis upon the aircraft and aircraft parts industries in Pennsylvania. So far there has been no great impact; in fact, the small-craft manufacturing component may have benefited since many firms chose small craft when commercial service was curtailed by the Arab oil embargo. As a consequence, the aeronautical engineer projection has been allowed to stand as it is found in Table 8. This also allows for greater aerospace involvement in the future.

The most interesting finding for Table 8 seems to be the projected decline of chemical and sales engineering for Pennsylvania. These declines could be reversed by a major firm entering Pennsylvania, such as Dupont, or a marked increase in the merchandising of highly technical products manufactured here. However, there is no current basis for assuming such events, especially in view of the economic climate.

The Problem of Estimating Growth for Baccalaureate Holders

The Table 8 projections are, of necessity, spuriously high in the sense that they are estimates of the number who have, or will have, classified themselves as engineers in responding to a census. Our concern is actually with that portion who have at least a baccalaureate degree in engineering. In addition, a small minority will have a degree in a scientific discipline other than engineering. Preliminary findings of the analysis of the 1970 census by the National Science Foundation[44] suggest that the figure for all enginee[illegible]n Table 8 should be 88.2 per cent of that shown and that 88 per cent of that figure will constitute the B.S. degree holders. This means that of 60,432 engineers, 53,180 will have B.S. degrees, though no breakdown in field is yet available. These findings are not used here because of this lack of information by field.[35]

Table 9 shows the percentage distribution of engineers by educational level, i.e., B.S. or higher, associate degree, no degree. These findings are based upon the original post-censal study of those calling themselves engineers in the 1970 census.[67] The figures shown are for the nation as a whole, but it can be assumed that they are not untypical of Pennsylvania. This makes is possible to determine the number of B.S. or higher degree engineers in Pennsylvania by using figures from Table 8.

Table 9

Percentage Distribution of U.S. Engineers by Type of Engineer and Possession of a Degree[a]

Type of Engineer	Bachelor's or Higher Per Cent	Associate Degree Per Cent	No Degree Per Cent
Aero/Astro	67	4	29
Chemical	85	1	14
Civil	60	4	36
Elec/Electronic	64	5	31
Industrial	51	4	45
Mechanical	61	3	36
Metals/Materials	72	2	26
Mining/Petroleum	80	1	19
Sales	55	3	42
Teachers/n.e.c.	62	4	34
Total	62	4	34

[a] Percentages derived from Table 1. "Engineers and Scientists in the 1970 Experienced Civilian Labor Force, by Age, Highest Degree Held and Sex in 1972," found in Characteristics of Persons in Engineering and Scientific Occupations: 1972, Technical Paper No. 33, published by the U.S. Bureau of the Census, 1974.

Table 10 results from the use of the percentages in Table 9 to identify the degree-holding engineers in the 1970 estimates and in the 1980 projections of Table 8. The figures in the last two column can now be used to project growth in the number of baccalaureate degree-holding engineers by assuming a compound rate of growth from 1970 to 1980 and by extrapolation to 1985. Table 11 shows the result of this process with 45,176 degree holding engineers, for example, seen as increasing at a compound rate of growth to 52,015 in 1980 and 55,976 in 1985.

Since extrapolation is, by its very nature, more subject to error, the results for the years 1981 to 1985 are less certain than for the years 1970-1980.

Estimations of Demand Due to Growth With No Energy Crisis Assumed

Table 12, based on Table 11, shows the projected demand due to growth for each specialty and for all engineers combined. If correct, the demand per year should have resulted in a demand for baccalaureate or higher degree-holding engineers, ranging from 627 per year in 1970 to 745 in 1980 and, finally, to 825 per year by 1985. Most would be required for civil, electrical/electronic, industrial and "other" engineers, such as bio-medical, nuclear, etc.

As might be expected in a pre-energy crisis projection, the growth in both mining and petroleum engineering is quite small. Undoubtedly these two areas would have shown a considerable increase in demand due to growth if the energy crisis had been taken into consideration by the Bureau of Labor Statistics.

Demand Due to Separation From the Work Force

Demand due to death, retirement and disability may be categorized generally as demand due to separations from the work force. Out-migration could be included here but it will be treated as a separate problem.

The Labor Market Information Section, Research and Statistics Division, Bureau of Employment Security, Department of Labor and Industry has published withdrawal rates for the various subspecialties and for engineers as a whole. The rates were based upon the known age distributions of the self-nominated engineers of the U.S. census. These withdrawal rates were published in August 1974 in *Pennsylvania Occupational Projections: 1970 and 1980 Total Resident Employment and Annual Average Job Openings by Occupational Category for the State and Its Major Areas*.[50]

Shown at the bottom of Table 13, the separation rates were multiplied by the column values of Table 11 to obtain estimated year-by-year separations due to death, disability and retirement for each engineering specialty listed. These estimates are spurious in that the age distribution of the B.S. or higher degree engineer differs from that of all engineers combined. However, it is assumed here that the amount of error is not enough to warrant an attempt to be more precise.

Table 10

Conversion of 1970 and 1980 BLS Modified Method B Projections of Employed Engineers to Estimates of Employed Engineers Holding a Bachelor's Degree in Pennsylvania

Field of Engineering	B.S. Conversion Ratio[b]	Total Employed 1970[e]	BLS Modified Method B 1980[c]	Estimated B.S. Holders 1970	Estimated B.S. Holders 1980
Aero-Astronautical	0.67	1,500	1,800	1,005	1,206
Chemical	0.85	3,918	3,756	3,330	3,193
Civil	0.60	9,288	10,997	5,573	6,598
Electrical-Electronic	0.64	15,178	17,849	9,714	11,423
Industrial	0.51	12,467	15,207	6,358	7,756
Mechanical	0.61	11,208	11,828	6,837	7,215
Metallurgical and Materials	0.72	2,228	2,370	1,604	1,706
Mining	0.80[c]	330	334	264	267
Petroleum	0.80[c]	88	99	70	79
Sales	0.55	4,784	4,705	2,631	2,588
Other, n.e.c.	0.62	12,565	16,104	7,790	9,984
All Engineers[a]	0.61[d]	73,554	85,049	45,176	52,015

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[a] All entries in this row are summations of the column entries with the exception of the B.S. conversion ratio of 0.61.

[b] Derived from national figures taken from a post-censal survey of engineers as found in Table 9.

[c] Mining and petroleum engineers were combined in the post-censal study of note b above. The same ratio is used here for both, although they may differ with regard to the proportion of degree holders.

[d] An actual result obtained by dividing 45,176 by 73,554 and 52,015 by 85,049, rounded off to two decimals. The post-censal survey of note b above gives this figure as 0.62, but a decision was made to use the obtained figure rather than to allocate.

[e] See Table 8.

Table 11

Compound Growth Estimates 1970-1985 by Engineering Specialty for Degree Holding Engineers (B.S. or Higher) in Pennsylvania Using BLS Modified Method B Based Projections for 1970 and 1980[a]

	Engineering Specialty											
Year	Aero-Astro-nautical	Chem-ical	Civil	Electrical Electronic	Indus-trial	Mechan-ical	Metallur-gical & Materials	Mining	Petro-leum	Sales	Others n.e.c.	All Combined
1970	1,005	3,330	5,573	9,714	6,358	6,837	1,604	264	70	2,631	7,790	45,176
1971	1,024	3,316	5,668	9,873	6,486	6,874	1,614	264	71	2,627	7,986	45,803
1972	1,042	3,302	5,764	10,034	6,616	6,911	1,624	265	72	2,622	8,186	46,438
1973	1,062	3,288	5,863	10,198	6,749	6,948	1,634	265	73	2,618	8,392	47,090
1974	1,081	3,275	5,962	10,365	6,884	6,986	1,644	265	73	2,614	8,603	47,752
1975	1,101	3,261	6,064	10,534	7,022	7,023	1,654	265	74	2,609	8,819	48,426
1976	1,121	3,247	6,167	10,706	7,163	7,061	1,664	266	75	2,605	9,041	49,116
1977	1,142	3,234	6,272	10,881	7,307	7,099	1,675	266	76	2,601	9,268	49,821
1978	1,163	3,220	6,379	11,059	7,454	7,138	1,685	266	77	2,596	9,501	50,538
1979	1,184	3,207	6,488	11,240	7,603	7,176	1,696	267	78	2,592	9,739	51,270
1980	1,206	3,193	6,598	11,423	7,756	7,215	1,706	267	79	2,588	9,984	52,015
1981	1,228	3,180	6,711	11,610	7,912	7,254	1,717	267	80	2,584	10,235	52,778
1982	1,251	3,166	6,825	11,800	8,071	7,293	1,727	268	81	2,579	10,492	53,553
1983	1,274	3,153	6,941	11,992	8,233	7,332	1,739	268	82	2,575	10,756	54,344
1984	1,297	3,140	7,059	12,188	8,398	7,372	1,749	268	83	2,571	11,026	55,151
1985	1,321	3,127	7,180	12,387	8,566	7,412	1,760	269	84	2,567	11,303	55,976

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[a] See Table 10 for the 1970 and 1980 BLS modified Method B. All projections shown here for 1981 to 1985 are extrapolations based upon the compound growth rate of 1970 to 1980.

Table 12

BLS Projected Baccalaureate or Higher Engineering Degree Demand Due to Growth for the Years 1971-1980 With No Assumptions Concerning the Impact of the Energy Crisis[a]

Engineering Specialty

Year	Aero-Astro-nautical	Chem-ical	Civil	Electrical Electronic	Indus-trial	Mechan-ical	Metallur-gical & Materials	Mining	Petro-leum	Sales	Others n.e.c.	All Combined
1971	19	(-14)[b]	95	159	128	37	10	-	1	(-4)[b]	196	627
1972	18	(-14)	96	161	130	37	10	1	1	(-5)	200	635
1973	20	(-14)	99	164	133	37	10	-	1	(-4)	206	652
1974	19	(-13)	99	167	135	38	10	-	-	(-4)	211	662
1975	20	(-14)	102	169	138	37	10	-	1	(-5)	216	674
1976	20	(-14)	103	172	141	38	10	1	1	(-4)	222	690
1977	21	(-13)	105	175	144	38	11	-	1	(-4)	227	705
1978	21	(-14)	107	178	147	39	10	-	1	(-5)	233	717
1979	21	(-13)	109	181	149	38	11	1	1	(-4)	238	732
1980	22	(-14)	110	183	153	39	10	-	1	(-4)	245	745
1981	22	(-13)	113	187	156	39	11	-	1	(-4)	251	763
1982	23	(-14)	114	190	159	39	10	1	1	(-5)	257	775
1983	23	(-13)	116	192	162	39	11	-	1	(-4)	264	791
1984	23	(-13)	118	196	165	40	11	-	1	(-4)	270	807
1985	24	(-13)	121	199	168	40	11	1	1	(-4)	277	825

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[a] Derived from Table 11 by subtracting the projected BLS modified Method B projection for a given year from that of the succeeding year.

[b] No growth. Rather a loss of numbers that must be used to reduce the demand due to separations.

Table 13

Estimates of Baccalaureate or Higher Degree Demand Due to Separation From the Work Force Based Upon the Growth Projections Made by the U.S. Bureau of Labor Statistics[a]

Engineering Specialty

Year	Aero-Astro-nautical	Chem-ical	Civil	Electrical Electronic	Indus-trial	Mechan-ical	Metallur-gical & Materials	Mining	Petro-leum	Sales	Others n.e.c.	All Combined
1971	10	46	120	131	97	119	23	10	1	48	130	734
1972	10	46	122	133	99	120	23	10	1	48	133	743
1973	10	45	124	136	101	120	23	10	-	48	137	753
1974	11	45	126	138	103	121	23	10	1	48	140	764
1975	11	45	129	140	105	121	24	10	1	47	144	775
1976	11	45	131	142	107	122	24	10	1	47	147	786
1977	11	45	133	145	109	123	24	10	1	47	151	797
1978	11	44	135	147	111	123	24	10	-	47	155	809
1979	12	44	137	149	113	124	24	10	1	47	159	820
1980	12	44	140	152	116	125	24	10	1	47	162	832
1981	12	44	142	154	118	125	24	10	1	47	167	844
1982	12	44	145	157	120	126	25	10	1	47	171	857
1983	13	43	147	159	123	127	25	10	-	47	175	869[c]
1984	13	43	150	162	125	127	25	10	1	47	180	882
1985	13	43	152	165	128	128	25	10	1	47	184	896
Separation Rate[b]	.0099	.0138	.0212	.0133	.0149	.0173	.0143	.0381	.01075	.0182	.0163	.0160

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[a] Based upon Table 11, which gives the projected growth for each area of specialization.

[b] Separation rates are derived from Pennsylvania Occupational Projections: 1970 and Projected 1980 Total Resident Employment and Annual Average Job Openings by Occupational Category for the State and its Major Areas, Labor Market Information Section, Research and Statistics Division, Pennsylvania Department of Labor and Industry, August 1974. These separation figures represent separation due to death, disability and retirement.

[c] The row figures for the engineering specialties do not necessarily add up to the figures shown in this column, but the discrepancy will not exceed two in any instance. Over the 15 years the row totals exceed the total of the figures in this column by only 12 times, or less than one per year.

It should be noted that the publication from which the separation rates are taken[50] also has 1970-1980 projections that differ from those in Table 8. These projections could have been used as the basis for the projections of growth and demand found in Tables 11 and 12. The projections actually used in Table 8 were preferred because the 1970 figures for occupations other than engineering were more congruent with other available, seemingly more accurate 1970 data for physicians,[11] dentists[17] and lawyers.[19] The projections also seem to agree with the existing, independently arrived-at projections of growth by 1980 mentioned earlier.

The Problem of Estimating Out-migration

There are no existing estimates of occupational migration rates for Pennsylvania. This area needs data badly, but nothing is currently available. The 1970 census, which included items relating to residence five years earlier, could be used to create a matrix reflecting movement in and out of a state. For that matter it could reflect migration in and out of a given occupation. To do it properly, however, one would have to analyze geographic and occupational mobility together, since they interact. When one changes occupations, he/she often changes geographic location. Such a study might require one or two years and a great deal of time and funds.

In light of this lack of data concerning migration by occupational category it was necessary to use what national figures were available. Usable data were found in Table 7 of the publication, Subject Reports: Mobility for States and the Nation,[66] which, when corrected to reflect an allocation of the nonrespondents among the known movers, resulted in Table 14 of this raport.

Manipulation of data on movers and nonmovers, over all states, found in this table (Table 14) resulted in the findings found in the last two columns. Of particular interest are the figures for each specialty in the last column headed, "Yearly Per Cent Leaving State." These percentage rates when applied to the estimated number of degree-holding engineers in Table 11, should give an estimation of the number out-migrating in each specialty for a given year if it is assumed that the rate will not change markedly over time and that these national rates actually apply to Pennsylvania's engineers.

The percentage rates of Table 14 have, therefore, been used to estimate engineering demand due to out-migration as Table 15 shows.

Table 14

Nonresponse Allocated Estimates of the Yearly Out-Migration Engineering Specialists from Their State of Residence Based Upon Residence Five Years Earlier as Found in the U.S. Census of 1970[a]

Engineering Specialty	Non-Mover Same House	Moved Same County	Moved Same State	Total Remaining State (1)	Total Moved Different State (2)	Total of Movers & Non-Movers (Col.1+Col.2) (3)	Per Cent Leaving State Over Five-Yr. Period (Col.2 ÷ Col.3) (4)	Yearly Per Cent Leaving State (Col.4 ÷ 5)
Aero-Astronautical	13,027	9,971	4,462	27,460	9,337	36,797	27.37	5.07
Chemical	8,216	6,116	3,643	17,975	9,947	27,922	35.62	7.12
Civil	32,783	24,844	15,258	82,885	17,422	100,307	17.37	3.47
Electrical-Electronic	57,872	44,660	25,694	128,226	41,365	169,591	24.39	4.88
Industrial	32,334	25,900	14,445	72,679	23,178	95,857	24.18	4.84
Mechanical	34,438	24,147	13,208	71,793	19,934	91,727	21.73	4.35
Metallurgical and Materials	2,767	1,938	1,029	5,734	2,125	7,859	27.04	5.41
Mining	714	361	245	1,320	707	2,027	34.88	6.98
Petroleum	1,483	1,187	1,356	4,026	1,976	6,002	32.92	6.58
Sales	8,689	7,783	4,536	21,008	7,913	28,921	27.36	5.47
Other, n.e.c.	34,918	28,129	16,025	79,072	25,017	104,089	24.03	3.81
All Engineers	227,241	175,010	99,909	502,160	158,903	661,063	24.04	4.81

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[a] Based on Table 7, "Mobility Status of Employed Males 25 to 64 years old by Selected Detailed Occupation: 1970" from Subject Reports: Mobility for States and the Nation (Pc(2) - 2B), U.S. Department of Commerce, Bureau of the Census, but nonrespondents who moved from an unknown geographic location are allocated among the known movers.

Table 15

Estimates of Engineering Demand Due to Out-migration From Pennsylvania Based Upon the Nationwide Out-migration Average for the States With No Assumption of an Energy Crisis[a]

Engineering Specialty

Year	Aero-Astro-nautical	Chem-ical	Civil	Electrical Electronic	Indus-trial	Mechan-ical	Metallur-gical & Materials	Mining	Petro-leum	Sales	Others n.e.c.	All Combined[c]
1971	52	236	197	482	314	299	87	18	5	144	304	2,203
1972	53	235	200	490	320	301	88	18	5	143	312	2,234
1973	54	234	203	498	327	302	88	18	5	143	320	2,265
1974	55	233	207	506	333	304	89	18	5	143	328	2,297
1975	56	232	210	514	340	305	89	18	5	143	336	2,329
1976	57	231	214	522	347	307	90	19	5	142	344	2,362
1977	58	230	218	531	354	309	91	19	5	142	353	2,396
1978	59	229	221	540	361	310	91	19	5	142	362	2,431
1979	60	228	225	548	368	312	92	19	5	141	371	2,466
1980	61	227	229	557	375	314	92	19	5	141	380	2,502
1981	62	226	233	567	383	315	93	19	5	141	390	2,539
1982	63	225	237	576	391	317	93	19	5	141	400	2,576
1983	65	224	241	585	398	319	94	19	5	141	410	2,614
1984	66	224	245	595	406	321	95	19	5	141	420	2,653
1985	67	223	249	604	415	322	95	19	5	140	431	2,692
Out-mi-gration Rate[b]	.0507	.0712	.0347	.0488	.0484	.0435	.0541	.0698	.0658	.0547	.0381	.0481

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[a] The figures in this table are obtained by multiplying the out-migration rate at the bottom of the table by the appropriate estimate of the number of engineers in the work force with a baccalaureate or higher degree as found in Table 11.

[b] See Table 14 for source. It is assumed here that Pennsylvania engineers would not deviate significantly in their tendency to migrate out, that the rate for all "census" engineers will be very similar to that of baccalaureate or higher degree holders, and that the 1965-to-1970 out-migration pattern will persist.

[c] The figures in this column differ slightly from the actual row totals, since they have been independently computed on the basis of an overall out-migration rate of 4.81 per cent as shown.

THE ENERGY CRISIS AND DEMAND

Since the projections cited earlier were developed, "energy crisis" became a household phrase and, despite the relative unconcern by the general public, there seems to be no doubt that it is real and is likely to become a serious issue in the near future.

No positive program has yet been agreed upon by the federal administration and the Congress, but it is probable that considerable efforts will have to be exerted to make the United States more self-sufficient in terms of energy that it now is. Indeed, recent announcements by the federal government indicate that dependency on foreign oil is increasing rather than decreasing. Overall, domestic production is going down. Pennsylvania with its large coal deposits and high-grade oil, should certainly be affected by any major response to the energy crisis.

To assess the probable impact of the nation's response to the crisis, one must modify the growth projections cited earlier in this report. Projections of demand, derived from these modified growth figures, should then permit an estimation of the need for engineers while dealing with the energy crisis.

It is obvious, of course, that no such assessment exists for Pennsylvania itself. A national impact study has, however, been made by the National Planning Association.[30] The results of this national study are utilized in this report on the assumption that Pennsylvania engineers and industries will be similarly affected.

Impacted Pennsylvania Industries

According to the National Planning Association report by Gutmanis,[30] the following industries will be affected by the response to the energy crisis: general contracting (home construction excluded), engine and turbine manufacture, power utilities, coal mining, crude petroleum and petroleum refining.

Table 16 shows the number (1970 census) of Pennsylvania engineers for each of these industries, plus the per cent of each type of engineer in that industry. Civil engineers in home construction were excluded.

Impact on Pennsylvania Engineering

Table 16 figures are carried over to Table 17 for two purposes: calculating the energy sector employment growth rate and correcting the BLS projections for 1980 to reflect the impact of the energy crisis.

Table 17 separates energy-related employment from nonenergy-related employment by subtracting the totals of Table 16 from the 1970 census figures in Table 8. These estimates of 1970 energy and nonenergy sector employment (columns 2 and 3 of Table 17) are then multiplied by either (1) the estimated growth for the energy sector as projected by Gutmanis[30] (column 4) or (2) the nonenergy growth projections of the Bureau of Labor Statistics in Table 8 (see column 5 of Table 17). Adding the two results for a given field of engineering gives the final corrected estimates of growth by 1980, as shown in the last two columns of Table 17. Apparently, the engineering profession in Pennsylvania by 1980, due to a response to the energy crisis, should number 89,979, compared with 85,049 in Table 8. In other words there should be a 22 per cent increase over 1970 instead of the 15.63 per cent increase projected in Table 8.

Table 16

Pennsylvania 1970 Engineering Occupation by Industry Matrix for the Six Industry Sectors Affected by Our Probable Response to the Energy Crisis[a]

Engineering Specialty	General Contracting[a]		Engine and Turbine Manufacture		Industry Sector[c]								TOTAL	
					Power Utilities		Coal Mining		Crude Petroleum		Petroleum Refining			
	#	%	#	%	#	%	#	%	#	%	#	%	#	%
Aero-Astronautical	0	0.00	0	0.00	5	0.22	0	0.00	0	0.00	0	0.00	5	0.06
Chemical	65	1.68	12	1.17	34	1.51	6	2.37	0	0.00	508	48.29	625	7.37
Civil	3,121[b]	80.63	10	0.98	178	7.90	21	8.30	0	0.00	55	5.23	3,385	39.91
Electrical-Electronic	157	4.06	167	16.31	1,331	59.02	22	8.70	0	0.00	101	9.60	1,778	20.96
Industrial	179	4.62	152	14.84	33	1.46	40	15.81	3	11.11	51	4.85	458	5.40
Mechanical	202	5.22	361	35.26	373	16.54	24	9.48	4	14.82	153	14.54	1,117	13.17
Metallurgical	21	0.54	24	2.34	5	0.22	0	0.00	0	0.00	10	0.95	60	0.70
Mining	0	0.00	0	0.00	4	0.18	133	52.57	0	0.00	0	0.00	137	1.61
Petroleum	0	0.00	0	0.00	0	0.00	0	0.00	20	74.07	35	3.33	55	0.65
Sales	28	0.72	35	3.42	93	4.12	0	0.00	0	0.00	26	2.47	182	2.15
Other, n.e.c.	98	2.53	263	25.68	199	8.83	7	2.77	0	0.00	113	10.74	680	8.02
All Engineers	3,871	100.00	1,024	100.00	2,255	100.00	253	100.00	27	100.00	1,052	100.00	8,482	100.00

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[a] From the matrix for Pennsylvania prepared by the United States Bureau of Labor Statistics from a modification of Method B found in "Tomorrow's Manpower Needs."

[b] Excludes home building.

[c] This table attempts to identify 1970 employment in those sectors comparable to those used by Gutmanis in his report entitled The Demand for Scientific and Technical Manpower in Selected Energy Related Industries 1970-85: A Methodology Applied to a Selected Scenario of Energy Output, A Summary, 1974, National Planning Association, Washington, D.C.

Table 17

Computation of Energy Crisis Modified 1980 Growth Using the National Estimates of the National Planning Association

Field of Engineering	1970 Census[a]	1970 Energy Sector Employment[b]	1970 Nonenergy Employment	Projected 1980 Energy Sector Growth[c]	Projected 1980 Nonenergy Sector Growth[d]	Projected 1980 Energy Corrected Growth[e]	1970-80 Energy Corrected Percentage Growth
				%	%		
Aero-Astronautical	1,500	5	1,495	00.00	20.00	1,800	20.00
Chemical	3,918	625	3,293	25.89	- 4.13	3,944	0.66
Civil	9,288	3,385	5,903	28.14	18.40	11,327	21.95
Electrical-Electronic	15,178	1,778	13,400	95.31	17.60	19,231	26.70
Industrial	12,467	458	12,009	45.00	21.98	15,313	22.83
Mechanical	11,208	1,117	10,091	148.75	5.33	13,428	19.81
Metallurgical and Materials	2,228	60	2,168	111.11	6.37	2,433	9.20
Mining	330	137	193	100.00	1.21	469	42.12
Petroleum	88	55	33	30.36	12.50	109	23.86
Sales	4,784	182	4,602	111.11	- 1.65	4,910	2.63
Other, n.e.c.	12,565	680	11,885	162.16	28.16	17,015	35.42
All Engineers	73,554	8,482	65,072	66.34	15.63	89,352 89,979[f]	21.48 22.33

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[a] Nonresponse allocated estimates developed by the U.S. Bureau of Labor Statistics for Pennsylvania projections using a modification of Method B from Tomorrow's Manpower Needs (See Table 8).

[b] Derived from the allocated 1970 figures of BLS using only those sectors of industry that are energy related, i.e., electric power generation, transmission and distribution; petroleum and natural gas extraction and refining; natural gas production, transmission and distribution; coal mining; nuclear power production and radioactive waste disposal; manufactures of selected durable equipment for electric companies and energy-related construction (See Table 16).

[c] Derived from projections of national growth listed in note b as found in The Demand for Scientific and Technical Manpower in Selected Energy-Related Industries, 1970-1985: A Methodology Applied to a Selected Scenario of Energy Output. A Summary by Ivars Gutmanis of the National Planning Association for the National Science Foundation.

[d] Derived from the 1970-80 projections of Table 8.

[e] Computed by applying the appropriate growth rates to the energy sector and non-energy sector figures for 1970 and summing the two, e.g., for chemical engineering, 625 x 0.9587 + 3.293 x 1.2589 = 3.944 and for civil engineering, 3,385 x 1.2814 + 5,903 x 1.1840 = 11,327. The 1980 estimate was left at 1,800 rather than 1,799 as computed.

[f] The actual total of the separate estimates. This total will be used later, since the nonenergy growth rates include the growth estimates for the energy-related sectors before the energy crisis and may be lower than would be the case if these sectors had been removed.

Table 18 allows a direct comparison of the original percentage distribution for 1980 with the energy crisis distribtuion for that year.

As seen in Table 18, the projected energy response distribution, when compared with 1970, will reduce the proportion of aeronautical, chemical, civil, mathematical, metallurgical and materials and sales engineers in the total mix and increase the proportion of electrical/electronic, industrial, mining, and "other" engineers. Petroleum engineers are seen as retaining their 1970 status of 0.12 per cent.

Also on the basis of the last two columns of Table 18, the projected energy crisis response will produce a larger proportion of electrical/electronic, mechanical and mining engineers than would be the case under the normal 1980 economic assumptions by the Bureau of Labor Statistics.

Conversion to Degree Holding Engineer Estimates

The energy crisis-corrected projections in Table 18 are spuriously high as estimates of the number of college-trained engineers because of the limitations of census based data. It has, therefore, been necessary to convert these projections in Table 18 to estimates of the number of 1970 and 1980 baccalaureate or higher degree holding engineers in Pennsylvania. The results of this conversion, found in Table 19, were arrived at by the same procedures used in Table 9. The estimated numbers of B.S. or higher degree-holding engineers in 1970 and 1980 under energy crisis-induced growth are in the last two columns of Table 19. These figures indicate growth from 45,176 in 1970 to 55,127 in 1980. The figure of 55,127 contrasts the figure of 52,015 in Table 10 where no energy crisis is assumed to exist.

The Table 19 estimates for 1970 and 1980 were then subjected, in Table 20, to the same basic process used in Table 11 to estimate the number of engineers in each specialty.

It is assumed in Table 20 that the response to the energy crisis will not materialize until 1976 and that during 1970 and 1975 the growth of a given specialty will follow the nonenergy crisis growth pattern of Table 11. The projections from 1975 to 1980 are, in turn, a result of the use of compound growth rates between the 1975 figures of Table 11 and the 1980 (energy crisis) estimates of Table 19. These compound growth rates, which were derived from the 1975 and 1980 data points, are also used to extrapolate beyond 1980 to 1985.

Demand Due to Energy Crisis Growth

Table 21 shows projections of demand due to growth, i.e., year-to-year change, based upon Table 20. As might be expected, a sharp upturn in demand is projected to occur in 1976 because of the assumption that the nation's response to the energy crisis will be formulated in 1975 and go into action in 1976.

Table 18

Projected 1970 to 1980 Change in Pennsylvania's Engineering Employment if the Energy Crisis Scenario of the National Planning Association is Implemented[a]

Types of Engineer	1970 Census[b]	1980 "Energy Crisis" Projections[c]	1970 Per Cent Distribution (%)	Projected 1980 Crisis Per Cent Distribution (%)	1980 BLS Distribution[d] (%)
Aero-Astronautical	1,500	1,800	2.04	2.00	2.12
Chemical	3,918	3,944	5.33	4.38	4.42
Civil	9,288	11,327	12.63	12.59	12.93
Electrical	15,178	19,231	20.63	21.37	20.99
Industrial	12,467	15,313	16.95	17.02	17.88
Mechanical	11,208	13,428	15.24	14.92	13.91
Mettalurgical and Materials	2,228	2,433	3.03	2.71	2.79
Mining	330	469	0.45	0.52	0.39
Petroleum	88	109	0.12	0.12	0.12
Sales	4,784	4,910	6.50	5.46	5.53
Other, n.e.c.	12,565	17,015	17.08	18.91	18.93
All Engineers	73,554	89,979	100.00	100.00	100.00

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[a] Based upon the study for the National Science Foundation by Ivars Gutmanis The Demand for Scientific and Technical Manpower in Selected Energy-Related Industries, 1970-1985: A Methodology Applied to a Selected Scenario of Energy Output, A Summary, National Planning Association, Washington, D.C., 1974.

[b] 1970 Census estimates as corrected by the Bureau of Labor Statistics by allocation of nonrespondents.

[c] From Table 17.

[d] See Table 8 for source.

Table 19

Conversion of 1970 and 1980 Energy Crisis Modified Projections of Employed Engineers to Estimates of Employed Engineers Holding a Bachelor's or Higher Degree in Pennsylvania

Field of Engineering	B.S. Conversion Ratio[b]	Total Employed 1970[e]	Projected Energy Crisis Employed 1980[f]	Estimated B.S. Holders 1970	Energy Crisis Estimate of B.S. Holders 1980
Aero-Astronautical	0.67	1,500	1,800	1,005	1,206
Chemical	0.85	3,918	3,944	3,330	3,352
Civil	0.60	9,288	11,327	5,573	6,796
Electrical-Electronic	0.64	15,178	19,231	9,714	12,308
Industrial	0.51	12,467	15,313	6,358	7,810
Mechanical	0.61	11,208	13,428	6,837	8,191
Metallurgical and Materials	0.72	2,228	2,433	1,604	1,752
Mining	0.80[c]	330	469	264	375
Petroleum	0.80[c]	88	109	70	87
Sales	0.55	4,784	4,910	2,631	2,701
Other, n.e.c.	0.62	12,565	17,015	7,790	10,549
All Engineers[a]	0.61[d]	73,554	89,979	45,176	55,127

[a] All entries in this row are summations of the column entries with the exception of the B.S. conversion ratio of 0.61.

[b] Derived from national figures taken from a post-censal survey of engineers as found in Table 9 of this report.

[c] Mining and petroleum engineers were combined in the post-censal study of note b. above. The same ratio was used for both, although there may be a difference between them with regard to the proportion of degree holders.

[d] An actual result obtained by dividing 45,176 by 73,554 and 55,127 by 89,985; 0.61 is obtained in each instance when rounded to two decimals. The post-censal survey of note b above gives this figure as 0.62 but a decision was made to use the obtained figure rather than to allocate.

[e] See Table 18.

Table 20

Growth Estimates 1970-1985 by Engineering Specialty for Degree Holding Engineers (B.S. or Higher) in Pennsylvania on the Assumption That Our Response to the Energy Crisis Will Begin in the Year 1976[a]

Engineering Specialty

Year	Aero-Astro-nautical	Chem-ical	Civil	Electrical Electronic	Indus-trial	Mechan-ical	Metallur-gical & Materials	Mining	Petro-leum	Sales	Others n.e.c.	All Combined
1970	1,005	3,330	5,573	9,714	6,358	6,837	1,604	264	70	2,631	7,790	45,176
1971	1,024	3,316	5,668	9,873	6,486	6,874	1,614	264	71	2,627	7,986	45,803
1972	1,042	3,302	5,764	10,034	6,616	6,911	1,624	265	72	2,622	8,186	46,438
1973	1,062	3,288	5,863	10,198	6,749	6,948	1,634	265	73	2,618	8,392	47,090
1974	1,081	3,275	5,962	10,365	6,884	6,986	1,644	265	73	2,614	8,603	47,752
1975	1,101	3,261	6,064	10,534	7,022	7,023	1,654	265	74	2,609	8,819	48,426
1976	1,121	3,279	6,204	10,867	7,173	7,242	1,673	284	76	2,627	9,141	49,687
1977	1,142	3,297	6,347	11,211	7,327	7,469	1,692	304	79	2,645	9,474	50,987
1978	1,163	3,315	6,493	11,565	7,485	7,702	1,712	326	81	2,664	9,820	52,326
1979	1,184	3,334	6,643	11,931	7,646	7,943	1,732	350	84	2,682	10,178	53,707
1980	1,206	3,352	6,796	12,308	7,810	8,191	1,752	375	87	2,701	10,549	55,127
1981	1,228	3,370	6,953	12,697	7,978	8,447	1,772	402	90	2,720	10,934	56,591
1982	1,251	3,389	7,113	13,099	8,149	8,711	1,793	431	93	2,739	11,333	58,101
1983	1,274	3,408	7,277	13,513	8,325	8,983	1,814	462	96	2,758	11,746	59,656
1984	1,297	3,427	7,445	13,940	8,504	9,264	1,835	495	99	2,777	12,174	61,257
1985	1,321	3,445	7,616	14,381	8,686	9,553	1,856	531	102	2,796	12,618	62,905

[a] See Table 11 for the figures for 1970-1975, when normal growth is assumed. The figures for 1976-1980 are compound interest estimates based upon the 1980 energy crisis projections of Table 19. The figures for 1981-85 are extrapolations based upon the projected 1975-1980 growth rate.

[b] The sum of the projected entries for a given year.

Table 21

Baccalaureate or Higher Degree Engineer Demand for Pennsylvania Due to Growth Assuming a Major Response to the Energy Crisis After 1975[a]

Engineering Specialty

Year	Aero-Astro-nautical	Chem-ical	Civil	Electrical Electronic	Indus-trial	Mechan-ical	Metallur-gical & Materials	Mining	Petro-leum	Sales	Others n.e.c.	All Combined
1971	19	(-14)[b]	95	159	128	37	10	0	1	(-4)[b]	196	627
1972	18	(-14)	96	161	130	37	10	1	1	(-5)	200	635
1973	20	(-14)	99	164	133	37	10	0	1	(-4)	206	652
1974	19	(-13)	99	167	135	38	10	0	0	(-4)	211	662
1975	20	(-14)	102	171	138	37	10	0	1	(-5)	216	674
1976	20	18	140	333	151	219	19	19	2	18	322	1,261
1977	21	18	143	344	154	227	19	20	3	18	333	1,300
1978	21	18	146	354	158	233	20	22	2	19	346	1,339
1979	21	19	150	366	161	241	20	24	3	18	358	1,381
1980	21	18	153	377	164	248	20	25	3	19	371	1,420
1981	22	18	157	389	168	256	20	27	3	19	385	1,464
1982	23	19	160	402	171	264	21	29	3	19	399	1,510
1983	23	19	164	414	176	272	21	31	3	19	413	1,555
1984	23	19	168	427	179	281	21	33	3	19	428	1,601
1985	24	18	171	441	182	289	21	36	3	19	444	1,648

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[a] See Table 20,from which the growth figures are derived.

[b] The negative figures in parentheses represent a loss rather than growth.

Demand Due to Separations

No table has been developed to reflect separations due to death, disability or retirement. It has been assumed instead that the pre-energy crisis estimates of Table 13 can be used here, since any new entrants attributable to the energy crisis will be young and not likely to die, become disabled or retire.

Demand Due to Out-migration

In Table 22, estimates of the out-migration rate for the historic past have been applied to the growth estimates of Table 20 in order to project the out-migration, by specialty, of Pennsylvania engineers under an energy crisis response assumption. These projections will err to the extent that the rising demand in other states reduces Pennsylvania's ability to retain and attract engineering talent. They would also err to some degree if the assumption of Pennsylvania being comparable to the other states is not in actual fact tenable.

The foregoing projections of demand under energy crisis and nonenergy crisis conditions will have to be compared with projections of the available supply of engineers before any assessment of actual need can be made. They are, in and of themselves, of little value unless we are able to also assess supply. Fortunately, it has proven to be possible to do this despite the difficulties entailed in such a process.

PENNSYLVANIA'S ENGINEERING SUPPLY

In an assessment of supply four basic problems arise. The first is obtaining valid and reliable historical data on engineering enrollments and degree output. The second is ascertaining the trends in the historical data to permit extrapolation into the future. The third is how to estimate the supply due to in-migration. The last problem, not dealt with here (see section on unmet need), is the question of the long-term future relative to population changes now foreseen as a consequence of (1) the declining birthrate, (2) the recent decline of college freshmen's interest in engineering,[5,6] (3) the increasing participation by women and minorities,[4,42,45] and (4) the recently reported decline in mathematical (SAT) aptitude scores, and the science and achievement scores of the National Assessment.[41,43,53]

The Problem of Valid and Reliable Data

Several data sources were initially examined as a possible basis for projecting supply. These sources were (1) the HEGIS data normally compiled by the Division of Educational Statistics in the Pennsylvania Department of Education and (2) the annual spring compilations of the Engineers Joint Council.

Consultation with the deans of the various engineering colleges in the state made it quite clear that they felt the HEGIS data to be inaccurate and insufficiently detailed. The Engineers Joint Council data were also seen as

Table 22

Baccalaureate or Higher Degree Engineering Demand for Pennsylvania Due to Out-Migration Assuming a Response to the Energy Crisis After 1975[a]

Engineering Specialty

Year	Aero-Astro-nautical	Chem-ical	Civil	Electrical Electronic	Indus-trial	Mechan-ical	Metallur-gical & Materials	Mining	Petro-leum	Sales	Others n.e.c.	All Combined[c]
1971	52	236	197	482	314	299	87	18	5	144	304	2,203
1972	53	235	200	490	320	301	88	18	5	143	312	2,234
1973	54	234	203	498	327	302	88	18	5	143	320	2,265
1974	55	233	207	506	333	304	89	18	5	143	328	2,297
1975	56	232	210	514	340	305	89	18	5	143	336	2,329
1976	57	233	215	530	347	315	90	20	5	144	348	2,390
1977	58	235	220	547	355	325	91	21	5	145	361	2,452
1978	59	236	225	564	362	335	93	23	5	146	374	2,517
1979	60	237	230	582	370	345	94	24	5	147	388	2,583
1980	61	239	236	600	378	356	95	26	6	148	402	2,652
1981	62	240	241	620	386	367	96	28	6	149	417	2,722
1982	63	241	247	639	394	379	97	30	6	150	432	2,795
1983	65	243	252	659	403	391	98	32	6	151	447	2,869
1984	66	244	258	680	412	403	99	34	6	152	464	2,946
1985	67	245	264	702	420	415	100	37	7	153	481	3,026
Out-Migration Rate[b]	.0507	.0712	.0347	.0488	.0484	.0435	.0541	.0698	.0658	.0547	.0381	.0481

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[a] See Table 20 from which the figures were derived. The out-migration rates shown at the bottom of each column were the basis of the derivation.

[b] See Table 14 for source of rates. It is assumed here that Pennsylvania engineers would not deviate significantly from the national rate, that the rate for all "census" engineers will be very similar to that for degree-holding engineers and that the 1965-1970 out-migration pattern will persist.

[c] Figures in this column may differ slightly from a row. These figures are an independent computation based on an out-migration rate for all engineers combined.

less accurate than they could be. This was because the estimates of fall enrollment, for freshmen especially, were made early in the spring and were, in many instances, projections rather than hard data.

It was therefore agreed that the Pennsylvania Association of Engineering Colleges would undertake a survey of potential and past manpower supply by using a survey form developed by the author of this report. This survey, entitled Report of The Pennsylvania Engineering Manpower Surveys From the Pennsylvania Association of Engineering Colleges, was carried out under the supervision of Dean Arthur Humphrey of the College of Engineering and Applied Science of the University of Pennsylvania and was completed by him in July of 1974.[31] Some corrected data were later obtained and inserted into the report in September of that year. The survey data were then used in computing the supply estimates and projections found here.

Pennsylvania's Engineering Graduates 1963-73

Table 23 summarizes survey data submitted by the Pennsylvania Association of Engineering Colleges on the number of engineers graduated with a bachelor of science, a master of science or a doctoral degree for each year from 1963 to 1973.[31] The numbers for each school, when summed, yielded figures suitable for an analysis of the total supply from Pennsylvania schools during this period.

Obviously, not all graduates can be expected to enter the Pennsylvania labor market. Some will undoubtedly work elsewhere; some will go on to graduate school; some will enter military service; and some will be unemployed, at least for a time. Further data on the rate of entry into these various post-graduate options is obviously needed.

Post Engineering Degree Activities

In 1971-72 William Toombs of The Pennsylvania State University carried out a study entitled The Comm-Bacc Study: Postbaccalaureate Activities of Degree Recipients from Pennsylvania Institutions 1971-72.[57] Although Toombs provided no detailed data for engineers in his report, he provided a special count from the raw data later. These special counts for engineering are in Table 24.

As can be seen, in 1971-72, the proportion of engineers obtaining employment related to their field of training was 46.6 per cent. Figures for the various specialties ranged from 27.3 per cent for aeronautical engineers to 57.2 per cent for civil engineers. In general, these findings seem to be consistent with the employment picture for engineers at the time. In fact, there was a great deal of publicity about the "high" unemployment of engineers, particularly of aeronautical engineers.

Ironically, the employment problems for the engineering graduate were far less than for any other type of graduate. Most of the so-called unemployment was found among aeronautical and systems engineers over forty-five who had worked in the recently reduced federal aerospace program.[16]

Table 23

Graduates from Pennsylvania Schools of Engineering 1963-1973[a]

Institution		1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973
Bucknell	B.S.	58	92	72	83	98	63	86	67	80	69	55
	M.S.	7	5	3	11	6	6	12	13	12	13	13
Carnegie	B.S.	268	263	224	228	233	238	260	232	265	192	213
	M.S.	98	96	123	124	135	130	131	98	129	84	98
	D.Eng.	36	43	41	48	55	61	52	50	59	44	50
Drexel	B.S.	284	358	337	293	333	323	364	382	278	321	307
	M.S.	156	169	161	175	198	193	153	109	75	123	160
	D.Eng.	-	-	-	1	13	3	11	12	21	28	22
Gannon	B.S.	NA	28	25	28	30	18	40	33	35	42	30
	M.S.								1	3	3	2
Lafayette	B.S.	132	114	110	94	113	100	140	141	109	108	100
Lehigh	B.S.	241	268	246	261	298	343	354	311	310	352	360
	M.S.	81	123	116	84	101	124	107	105	110	100	121
	D.Eng.	18	22	34	38	40	50	55	52	50	43	43
Un. of Pa.	B.S.	93	97	81	80	90	101	93	96	96	89	80
	M.S.	151	168	188	167	189	183	186	149	170	138	151
	D.Eng.	17	24	33	50	49	55	90	74	60	67	58
Penn State	B.S.	609	600	660	606	618	641	716	706	636	691	709
	M.S.	89	115	185	169	206	206	206	218	248	223	243
	D.Eng.	22	21	24	32	36	34	44	57	43	49	38
Un. of Pitt.	B.S.	227	337	313	246	247	295	320	284	426	412	349
	M.S.	47	69	86	86	79	89	106	75	91	99	120
	D.Eng.	21	15	13	8	12	32	22	26	19	22	20
Swarthmore	B.S.	14	13	16	17	11	14	11	13	11	13	14

Table 23
(continued)

Institution	Degree	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973
Villanova	B.S.	181	190	189	180	206	192	181	175	191	162	207
	M.S.	22	33	15	34	29	35	42	44	39	53	56
Widener	B.S.	45	50	30	33	[illegible]	38	51	44	45	36	33
	M.S.						2	3	9	6	10	13
Total	B.S.	2,152[b]	2,410	2,303	2,149	2,304	2,366	2,616	2,484	2,482	2,487	2,457
	M.S.	641	778	877	850	943	968	946	821	883	846	977
	D.Eng.	114	125	145	177	205	235	274	271	252	253	231

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[a] From Arthur Humphrey's Report on the Pennsylvania Engineering Manpower Supply Surveys from the Pennsylvania Association of Engineering Colleges, 1974, compiled by the association at the request of the Bureau of Information Systems.

[b] Does not include Gannon College. The correct figure would be about 2,180 if Gannon had the same number of B.S. degree recipients as it did in 1964.

Table 24

Engineering Degree Recipient Activities Following Graduation 1971-72

Total Respondents	Aero-Astro-nautical	Chemi-cal & Petro-leum	Civil	Elec-trical	Mechan-ical	Geophy-sical and Mining	Indus-trial	Metal-lurgical	Others n.e.c.	All Fields Combined
	%	%	%	%	%	%	%	%	%	%
A. Employment Status										
Related Employment	27.3	47.3	57.2	50.5	49.0	38.4	34.9	38.3	33.6	46.6
Unrelated Employment	4.5	3.3	3.3	4.1	8.2	30.8	8.1	4.2	15.1	6.4
Seeking Employment	22.7	15.2	14.8	19.2	11.7	7.7	33.7	12.8	17.1	17.2
Not Seeking Employment	4.5	0.5	3.3	3.5	1.5	0.0	7.0	0.0	2.0	2.6
B. Total Work Force	54.5	66.3	78.6	77.3	70.4	76.9	83.7	55.3	67.8	72.8
C. Place of Employment										
1. In Pennsylvania	42.9	48.2	40.7	50.8	53.6	33.3	54.0	60.0	42.7	48.6
Same Co. as Educated	28.6	15.3	18.6	19.6	16.1	0.0	18.9	0.0	8.5	16.1
Adjacent County	0.0	9.4	7.0	10.1	12.5	0.0	2.7	33.3	22.0	11.4
Elsewhere in Pa.	14.3	23.5	15.1	21.1	25.0	33.3	32.4	26.7	12.2	21.1
2. Out-of-State	57.1	51.8	59.3	49.2	46.4	66.7	46.0	40.0	57.3	51.4
Adjacent State	0.0	32.9	38.4	30.6	23.2	55.6	24.4	40.0	23.2	29.3
Elsewhere In U.S.	57.1	18.8	16.3	18.1	21.4	11.1	21.6	0.0	23.2	19.3
Abroad	0.0	0.0	4.6	0.5	1.8	0.0	0.0	0.0	10.9	2.5
D. Other Activity	45.5	33.7	21.4	22.7	29.6	23.1	16.3	44.7	32.2	27.2
Military Service	31.8	9.2	8.2	8.4	6.6	7.7	4.7	25.5	8.5	9.0
Graduate School	13.7	24.5	13.2	14.3	23.0	15.4	11.6	19.2	23.7	18.2
E. Numerical Base										
Number Employed	7	85	86	199	112	9	37	15	82	632
Number Reporting	22	184	182	370	196	13	86	47	152	1,252
Number of Nonrespondents	21	93	111	212	218	6	79	26	109	875

[a] Based upon a special count transmitted to the author of this report by William Toombs of The Pennsylvania State University, who used raw data from his Comm-Bacc Study. See bibliography for citation of the Comm-Bacc report.

Table 24 also shows that 48.6 per cent of those who found employment remained within the Commonwealth of Pennsylvania. Retention rates for the specialties ranged from 42.7 per cent for the general "other, n.e.c." classification to 60 per cent for metallurgical engineering degree recipients. The lowest figure was for aeronautical engineers, of whom only 42.9 per cent remained in the state.

During this period, only 27.2 per cent of all engineering degree graduates in Table 24 entered an activity other than employment. This varied widely among the specialties: 45.5 per cent of the aeronautical engineers entering either military service (31.8 per cent) or graduate school (13.7 per cent). In contrast only 4.7 per cent of the industrial engineers entered the military and only 11.6 per cent went on to graduate study. As might be expected, the strongest participation in graduate school was by chemical and petroleum engineers (24.5 per cent), mechanical engineers (23.0 per cent), metallurgical engineers (19.2 per cent) and other engineers, n.e.c. (23.7 per cent). Other engineers, n.e.c., includes nuclear engineering, bio-medical engineering and other highly specialized areas. These specialties tend to be highly technical fields for which graduate education might well be desirable or even mandatory, e.g., nuclear engineering.

When using this table, one must remember that 1970-71 was somewhat unusual. In a contrasting period of high demand and low supply it is unlikely that relevant employment rates would be so low or unemployment figures this high. It has, therefore, been assumed in the projections of this report that (1) military entry rates will drop sharply, (2) graduate study will be less attractive, (3) virtually all of the graduates will be employed in related fields and (4) retention rates will nevertheless remain the same, i.e., that state employers will remain at least as competitive as in the past.

Freshman/Five-Year Program Sophomore Graduate Projections

Table 25 represents Pennsylvania Association of Engineering Colleges data on the number of freshman and, for the five-year programs, the number of sophomores enrolled in engineering. It then compares these totals (freshmen and sophomores combined) with the number of graduates at the end of the fourth year. The overall ration of freshmen/sophomores to graduates was 0.6268; this means the number of graduates (B.S.) was approximately 62 per cent of the freshman/sophomore figure.

This ratio was then used to project the number of graduates in 1973-74 and 1975-76. The real problem now is to project beyond 1975-76 in the absence of any data on the number of freshmen beyond the 1972-73 school year.

Projection of Graduates Beyond 1976

Table 26 indicates the overall growth of the freshman class in all institutions of higher learning, plus growth for the various major segments of higher education from 1966 through 1973. This information, if compared with the known number of high school graduates, should yield a ratio which can be applied to existing projections of high school graduates. The result will be projections of the number of freshmen entering Pennsylvania's colleges.

Table 25

Projections of Pennsylvania Engineering Graduates to 1976 Using the Average Ratio of Four-Year Program Freshmen and Five-Year Program Sophomores to Graduates Four Years Later[a]

Institution	Data Year and Year of Graduation										
	1962-63 1965-66	1963-64 1966-67	1964-65 1967-68	1965-66 1968-69	1966-67 1969-70	1967-68 1970-71	1968-69 1971-72	1969-70 1972-73	1970-71 1973-74	1971-72 1974-75	1972-73 1975-76
Bucknell	147	133	113	141	130	133	127	89	152	119	104
Carnegie-Mellon	NA	239	237	217	190	222	208	230	212	237	183
Drexel[b]	388	514	499	462	465	417	462	455	437	418	296
Gannon	NA[c]	NA[c]	155	158	168	174	90	129	125	76	62
Lafayette	144	143	161	181	190	156	175	167	132	125	109
Lehigh	454	445	457	460	440	464	459	478	441	448	359
Un. of Penna.	122	124	148	136	137	141	148	155	132	162	98
Penn State Un.[b]	1,050	1,127	1,217	1,514	1,431	1,462	1,496	1,555	1,414	1,253	1,125
Un. of Pitts.	NA	NA	NA	NA	NA	312	402	325	339	292	257
Swarthmore	29	30	26	22	24	30	23	26	32	31	24
Villanova	304	326	339	306	294	324	279	333	304	201	166
Widener	66	72	82	92	75	73	65	64	49	72	38
Total	2,704	3,153	3,434	3,689	3,544	3,908	3,934	4,006	3,769	3,434	2,821
Graduates[d]						2,482	2,487	2,457			
Projected Graduates[e]						2,450	2,466	2,511	2,362	2,152	1,768
Percentage Error						-1.3	-0.8	2.2			

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[a] Data entries are taken from Arthur Humphrey's Report on the Pennsylvania Engineering Manpower Supply Surveys from the Pennsylvania Association of Engineering Colleges, College of Engineering and Applied Science, University of Pennsylvania, January 1974.

[b] Data entries are for five-year program sophomores.

[c] Not available because Gannon shifted to a four-year program in 1968.

[d] Graduates are shown only for the years that data are available over all schools.

[e] Projections are based on an overall ratio of .6268 over the three years for which complete data are available.

Table 26

Full-Time First-Time Freshmen at Four-Year Colleges and Universities in Pennsylvania, Fall 1966-1973

	1966	1967	1968	1969	1970	1971	1972	1973
Total	52 286	53 815	56 427	62 848	61 549	61 505	60 622	59 694
State-Owned Institutions	12 197	12 534	13 000	15 254	14 279	14 022	13 607	14 118
State-Related Commonwealth Universities	13 100	14 768	15 259	16 579	15 279	16 201	16 311	16 188
Private State-Aided Institutions	4 064	4 208	4 273	4 873	4 878	4 962	4 470	4 192
Private Colleges and Universities[a]	22 925	22 305	23 895	26 142	27 113	26 320	26 234	25 196

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[a] Private communication from Division of Educational Statistics, Commonwealth of Pennsylvania, Department of Education, Bureau of Information Systems, August 22, 1974.

[b] Excludes theological seminaries.

Table 27 translates high school graduate figures to four-year college enrollment ratios for 1966 through 1973; and it indicates an overall ratio of 0.33. Use of 0.33 will permit a "mean ratio" prediction of freshman class size from 1966 to 1973.

The freshman class projections in Table 27 are then transferred to Table 28 (column 1). For the period 1967 through 1973, they are contrasted with the engineering freshman/five-year program sophomore figures of Table 25 so that a series of historical ratios can be developed.

As seen in Table 28 the ratios have historically declined in size each year from 1967 to 1973. This decline is presumably a consequence of adverse publicity about unemployment among engineers and of a declining interest in scientific and technical occupations among students of the 1960s.

It is assumed, in Table 28, that this situation will reverse itself due to (1) the increasing difficulty of college graduates finding employment in popular degree areas, such as education, liberal arts, and, to a lesser degree, the physical, biological and social sciences and (2) the projected strong demand for engineers. Since no exact estimate of the reversal trend was possible, it was further assumed that any reversal would be a mirror image of the previous historical decline until it reached the 1967 level and then be held steady.

The last column of Table 28 lists freshman/five-year sophomore enrollment projections based on these mirror image ratios. Interestingly, data published April 28, 1975, by The Chronicle of Higher Education indicates that the 1963-1973 decline was reversed in 1974 with a 22 per cent increase over 1973's freshmen enrollment figures compiled by the Manpower Commission of the Engineers Joint Council.[24] Table 28 also indicates a marked reversal of the trend in 1974 and a similar increase, 20.7 per cent. It may be that the ultimate ratio of Table 28 should be higher than the 7.26 per cent limit shown. The author believes that students' rejection of scientific and technical occupations will persist to some degree, not only because of the ideology that rejects technology, but also because the federal government effectively but inadvertently put over the message that one cannot count on employment in any occupation where government policy and priority decisions can suddenly eliminate a large number of job openings.

Final Projections of Graduates Produced and Retained

In Table 29 the actual and projected freshmen/sophomore figures of Table 28 are multiplied by the 0.6268 ratio. This ratio is used to project the number of engineering graduates from 1974 to 1987.

Since an extrapolation of demand due to growth has been made from 1980 to 1985 and because such extrapolations are risky, the subsequent tables will go only to 1983. This will make the extrapolated projections reasonably conservative.

Table 27

Projection of College Freshmen Enrollment in Four-Year Baccalaureate Institutions of Higher Learning

Year	High School Graduates[a]	Freshmen (Four-Yr.) College Enrollments[b]	Ratio Enrollments High School Graduates	Mean Ratio Prediction of Freshmen	Percentage Error
1966	168,531	52,286	.31	55,615	6.37
1967	167,996	53,815	.32	55,439	3.02
1968	167,533	56,427	.34	55,286	-2.02
1969	178,397	62,848	.35	58,871	-6.33
1970	182,690	61,549	.34	60,288	-2.05
1971	182,690	61,505	.35	60,288	-1.98
1972	186,569	60,622	.33	61,568	1.56
1973	181,621	59,694	.33	59,935	0.40
Total	1,416,027	468,746	.33	467,289	0.31
	Projected				
1974	187,800			61,974	
1975	191,300			63,129	
1976	189,200			62,436	
1977	188,100			62,073	
1978	185,200			61,116	
1979	183,400			60,522	
1980	176,600			58,278	
1981	173,000			57,090	
1982	170,100			56,133	
1983	160,100			52,833	

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[a] From Table 7, *Selected Educational Statistics for Pennsylvania to 1983-84: Projections*, Pennsylvania Department of Education, 1974.

[b] Data provided by the Division of Educational Statistics of the Bureau of Information Systems, Pennsylvania Department of Education. See Table 26.

Table 28

Computation of the Ratio Between the Number of Engineering Four-Year Program Freshmen or Five-Year Program Sophomores and the Number of College Freshmen for the Years 1967-1973 and Projections of Engineering Freshmen/Five-Year Sophomores Figures to Fall 1979

Year (Fall)	Four-Year College Freshmen[a]	Engineering Program Freshmen/ Sophomores[b]	Percentage Ratio	Predicted Engineering Program Freshmen/ Sophomore Ratio[c]	Predicted Freshmen/ Five-Year Sophomores[d]
1967	53,815	3,908	7.26		
1968	56,427	3,934	6.97		
1969	62,848	4,006	6.37		
1970	61,549	3,769	6.12		
1971	61,505	3,434	5.58		
1972	60,622	2,821	4.65		
1973	59,694	NA		4.00	2,387
	Projected				
1974	61,974			4.65	2,882
1975	63,129			5.58	3,523
1976	62,436			6.12	3,821
1977	62,073			6.37	3,954
1978	61,116			6.97	4,260
1979	60,522			7.26	4,394
1980	58,278			7.26	4,231
1981	57,090			7.26	4,145
1982	56,133			7.26	4,075
1983	52,833			7.26	3,836

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[a] From Table 27, where the number of four-year college freshmen is 33 per cent of the number of high school graduates for that year; and freshmen enrollments are then projected from projected high school enrollments.

[b] Derived from Table 25, where four-year program freshmen and five-year program sophomores are totaled over all schools of engineering.

[c] Assumes an exact reversal of trend as a conservative estimate. It may be that students will turn to engineering in large numbers sooner, since the job market for engineers is holding up even in the present (1974-75) economic recession, according to information received from the College Placement Council.

[d] The result of multiplying the projected ratio of the previous column by the projected four-year college freshmen enrollment.

Table 29

Final Projections of the Number and Retention of Engineering Graduates to the Year 1987

Base Year	Graduation Year	Projected Freshmen/ Sophomore[a]	Projected Graduates[d]	Projections of Graduates Retained in Pa.[e]
1970	1974	3,769[b]	2,362[b]	1,148
1971	1975	3,434	2,152	1,046
1972	1976	2,821	1,768	859
1973	1977	2,387[c]	1,496	727
1974	1978	2,882	1,806	878
1975	1979	3,523	2,208	1,073
1976	1980	3,821	2,395	1,164
1977	1981	3,954	2,478	1,204
1978	1982	4,260	2,670	1,298
1979	1983	4,394	2,754	1,338
1980	1984	4,231	2,652	1,289
1981	1985	4,145	2,598	1,263
1982	1986	4,075	2,554	1,241
1983	1987	3,836	2,404	1,168

[a] Projections of the number of freshmen in engineering programs or, in the case of five-year programs, of sophomores in engineering.

[b] Underlined figures are from Table 25.

[c] Figures from this point down are from Table 28, in which projections of the number of freshman/sophomore enrollments have been made based upon a supposed reversal in engineering enrollments as a proportion of all four-year college enrollments.

[d] Figures in this column are derived from the first column according to the rate of 0.6268 from Table 25.

[e] Based upon a ratio of 0.486 derived from detailed data on engineers supplied by William Toombs and derived by him from raw data used in preparing his report entitled The Comm-Bacc Study: Postbaccalaureate Activities of Degree Recipients from Pennsylvania Institutions 1971-72, Report No. 23, Center for the Study of Higher Education, The Pennsylvania State University, August 1973. See Table 24 of this report for the computation of the ratio.

It should be noted, however, that the picture shown in Table 29 is one of declining enrollment and of a decline in graduates through to 1987. Table 29 is, therefore, consonant with as-yet-unpublished population projections (Tables 62 and 63) by the Bureau of Information Systems. They suggest a peak enrollment for higher education in 1978, with the largest high school graduating class becoming college freshmen in 1975. After 1980 the 18-21 year olds will decline in number. The data suggest that there will be at least 24 per cent fewer people of college age (18-21) in 1990 than in 1975. This does not, of course, bode well for the supply of engineers if demand continues to be high and if there is no marked increase in the proportion entering engineering.

One factor that should ameliorate the situation somewhat is the current increase in the number of women entering into engineering programs. Unfortunately, data on sex and minority representation was not provided by most of the institutions surveyed, so there is no precise estimate of the impact of women. The male participation rate is fairly close to the ability limit that successful science and engineering students must surpass. Women have not reached that level yet. Currently, 12 per cent of Pennsylvania's engineering students are women and 4 per cent are blacks.

One study suggests that only 2.5 per cent of the general population possess the requisite abilities for careers in science and engineering.[12] Since the female has been statistically less likely than the male to possess the requisite mathematical, spatial visualization and verbal skills because of culturally induced or genetic differences, obviously the participation rate for women in engineering is not likely to equal that of men for some time, if ever. Enrollment of talented, highly able females with high levels of motivation has recently become a reality and represents an encouraging trend. Certainly, increased participation by females and the anticipated decreased demand for scientists may help ameliorate the anticipated sharp decline in engineering graduates after 1983 (See Tables 62 and 63).

Projections by the Schools of Engineering

One item in the Association of Engineering Colleges survey[31] asked about projections of the number of degrees to be awarded through 1983 (See Table 30). Unfortunately, not all participating institutions were willing or able to make such projections and corrections had to be made to project the overall growth. It was assumed that the nonreporting institutions would grow proportionately to the projected overall growth of the reporting schools.

The deans of the engineering schools saw a sharp upturn in B.S. degrees in 1977. However, the upturn in freshmen cited earlier suggests that this upturn is more likely to occur in 1978.

Table 31 compares projections by the deans with those developed for this study. As can be seen, the deans seem to be more optimistic about the number graduated (B.S. degree) in the immediate future than the projections developed by the author. The primary difference seems to be for the years 1976 to 1979, when the deans foresee a great many more B.S. degrees than the author's historical data-based projections indicate.

Table 30

Projections of Bachelor Degree Output Made by the Engineering Schools and Adjusted Totals[a]

Institution	1973-74	1974-75	1975-76	1976-77	1977-78	1978-79	1979-80	1980-81	1981-82	1982-83	Totals
Bucknell	83	68	60	66	72	82	95	100	100	100	826
Carnegie	180	170	170	280	230	230	230	230	230	230	2,180
Drexel	218	305	230	210	220	259	323	324	325	325	2,839
Gannon	30	(28)[c]	(26)[c]	(28)[c]	(29)[c]	(31)[c]	(33)[c]	(34)[c]	(35)[c]	(36)[c]	310
Lafayette	72	72	92	120	98	100	100	100	100	100	954
Lehigh	342[d]	301	299	299	320	326	329	315	315	317	3,163
Un. Penna.	77	96	85	95	105	110	120	130	130	130	1,078
Penn State	663	634	573	613	653	683	709	739	777	814	6,858
Un. Pitt.	347	327	297	295	330	355	374	389	400	415	3,529
Swarthmore	17	20	22	25	(26)[c]	(28)[c]	(30)[c]	(31)[c]	(32)[c]	(33)[c]	264
Villanova	190	130	105	110	125	(133)[c]	(141)[c]	(144)[c]	(147)[c]	(150)[c]	1,375
Widener	27	30	30	36	46	55	59	66	71	71	491
Total	2,346	2,181	1,989	2,177	2,254	2,392	2,543	2,602	2,662	2,721	23,867
Actual or Estimated % of Growth[b]	-4.52	-7.04	-8.82	9.48	3.53	6.08	6.32	2.31	2.30	2.21	

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[a] Based upon data from Arthur Humphrey's Report on the Pennsylvania Manpower Supply Survey from the Pennsylvania Association of Engineering Colleges.

[b] Based upon the actual projection values given in the report, i.e., those not in parentheses.

[c] Values in parentheses arrived at by the use of overall percentage growth based upon the assumption that these schools will grow as much as the other schools, collectively, will grow (percentages used are at bottom of table).

[d] Actual value rather than a projection.

Table 31

A Comparison Between Projections Derived from Historical Data and the Projections Made by the Schools of Engineering in Response to a Survey Instrument

Projection Year	Data Based Projections[a]	Survey Response Projections[b]	Per Cent Difference
1973-74	2,362	2,346	2.58
1974-75	2,152	2,181	5.01
1975-76	1,768	1,989	19.39
1976-77	1,496	2,177	32.42
1977-78	1,806	2,254	17.46
1978-79	2,208	2,392	9.83
1979-80	2,395	2,543	7.07
1980-81	2,478	2,602	0.85
1981-82	2,670	2,662	- 3.45
1982-83	2,754	2,721	- 0.33
TOTAL	22,089	23,867	7.45

[a] From Table 29.

[b] From Table 30.

[illegible] 74

A consideration of Table 30 led to a decision to not utilize the projections made by the schools themselves because the author's projections seem more conservative with regard to the immediate future and possibly better tied to actual data.

The Difficult Problem of Projecting Supply for the Various Engineering Specialties

It seems reasonably to suppose that the number of baccalaureate engineering graduates in the various specialties will vary markedly from year to year depending on the anticipated or current demand perceived by the students when they choose their engineering curriculum. This variability should make projection of the supply of each type of engineer more difficult than the projection of the supply of engineers in general. Such proved to be the case with the engineering degree survey[31] data for Pennsylvania.

Baccalaureate Graduates by Degree Area

Table 32 summarizes the number of baccalaureate degrees awarded from 1964 to 1973 for each engineering degree field along with the percentage that each type of degree represented out of all degrees awarded that year.

As Table 32 illustrates, the proportion of degrees awarded in any given specialty varied considerably over the years with no consistent overall trend.

In light of this, it was necessary to assume that the projected rapid increase in demand, relative to supply, would result in the number trained for a given specialty rising to the largest value found during the period of 1964 to 1973.

The proportion that each maximum figure for 1964 to 1973 was of the total of the maximums was then computed (Table 33) and listed beside the proportions found for 1973. It was then assumed, arbitrarily, that the long-term trend would be close to the mean of the two, i.e., the 1973 proportions and the 1964-73 maximum figure proportions The resulting mean values are to be found in the last column of Table 33.

In Table 34 these mean value proportions are then used to project the number of graduates in each degree area of specialization for the years 1974 to 1983. The projections themselves are arrived at by multiplying the mean value proportions ot Table 33 (last column) times the projected baccalaureate graduate figures of Table 29.

The projections in Table 34 do not, however, take into account the probable impact of the energy crisis upon the demand for mining engineers. The University of Pittsburgh has indicated in the survey[31] that it will reactivate its program. Penn State has also indicated a marked increase in its production of mining engineers. Table 34 figures for mining engineers have, therefore, been appropriately increased in Table 35 and the other Table 35 figures reallocated to retain the same overall output figures shown in Table 34.

Table 32

The Proportion and Number of Engineering Baccalaureate Graduates 1964-73 by Degree Area[a]

Degree Field	Statistics	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973
Aero-Astronautical	Per Cent Number	2.2 (51)	3.5 (78)	4.1 (85)	3.4 (77)	3.0 (70)	3.9 (100)	4.5 (109)	4.0 (97)	2.5 (61)	1.5 (36)
Chemical	Per Cent Number	12.0 (273)	13.5 (303)	11.4 (239)	13.4 (299)	13.9 (319)	12.9 (327)	11.9 (286)	12.9 (314)	12.5 (301)	11.8 (281)
Civil	Per Cent Number	11.9 (270)	12.6 (284)	12.8 (268)	11.5 (257)	11.9 (273)	13.9 (352)	13.1 (317)	14.3 (346)	15.5 (373)	18.4 (437)
Electrical	Per Cent Number	35.3 (803)	32.4 (729)	33.6 (702)	31.2 (697)	30.0 (687)	29.4 (744)	28.4 (684)	26.4 (641)	28.6 (687)	27.6 (654)
Industrial	Per Cent Number	5.4 (123)	6.5 (146)	6.1 (127)	6.3 (140)	7.6 (174)	7.2 (183)	6.5 (157)	6.7 (162)	6.9 (166)	5.6 (132)
Mechanical	Per Cent Number	22.2 (504)	21.0 (473)	22.0 (459)	24.9 (557)	23.4 (536)	22.3 (566)	23.7 (572)	24.4 (591)	22.7 (544)	22.4 (531)
Metallurgical, Ceramic Materials	Per Cent Number	7.3 (167)	6.7 (150)	5.5 (116)	5.7 (128)	5.7 (131)	6.7 (169)	7.1 (171)	5.9 (142)	5.3 (127)	5.4 (129)
Mining	Per Cent Number	0.3 (8)	0.3 (6)	0.6 (12)	0.4 (9)	0.9 (20)	0.5 (13)	0.4 (9)	0.7 (18)	0.7 (16)	0.6 (15)
Petroleum	Per Cent Number	0.4 (9)	0.4 (9)	0.3 (7)	0.3 (6)	0.9 (21)	0.3 (8)	0.5 (11)	1.5 (36)	0.9 (22)	0.9 (21)
Others, n.e.c.	Per Cent Number	2.9 (65)	3.1 (70)	3.6 (75)	2.9 (65)	2.7 (62)	2.8 (70)	4.0 (96)	3.2 (78)	4.2 (102)	5.7 (135)
Total	Per Cent Number	100.0 (2,273)	100.0 (2,248)	100.0 (2,090)	100.0 (2,235)	100.0 (2,293)	100.0 (2,532)	100.0 (2,412)	100.0 (2,425)	100.0 (2,399)	100.0 (2,371)

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[a] Data on the number of graduates taken from the Arthur Humphrey *Report on the Pennsylvania Engineering Manpower Supply Surveys from the Pennsylvania Association of Engineering Colleges*.[31]

Table 33

Estimate of the Proportion of Total Engineering Supply to be Allocated to Each Specialty Area Based Upon an Average of the 1973 Proportions and the Proportion Obtained Using Historical Maximum Output Figures[a]

Specialty Area	1964-73 Maximum Number	Number in 1973	Maximum 1964-73 Proportions	1973 Proportions	Mean Proportions
			%	%	%
Aero-Astronautical	36[b]	36	1.31	1.52	1.41
Chemical	327	281	11.94	11.85	11.90[c]
Civil	437	437	15.96	18.43	17.20[c]
Electrical	803	654	29.32	27.58	28.45
Industrial	183	132	6.68	5.57	6.12
Mechanical	591	531	21.58	22.40	21.99
Metallurgical, Ceramic & Materials	171	129	6.24	5.44	5.84
Mining	20	15	0.73	0.63	0.68
Petroleum	36	21	1.31	0.89	1.10
Others, n.e.c.	135	135	4.93	5.69	5.31
All Engineers	2,739	2,371	100.00	100.00	100.00

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[a] Numerical data from Table 32.

[b] The actual maximum figure is 109, but it has been arbitrarily assumed here that the output will not return to this level because Piper Aircraft has relocated in Florida and Sikorsky has not grown appreciably.

[c] Arbitrarily rounded to larger numbers from 11.895 and 17.195 due to hypotheses as to what would happen to aeronautical and industrial growth in contrast.

Table 34

Projection of Engineering Baccalaureate Graduates by Degree Field

Year	Aero-Astro-nautical	Chem-ical	Civil	Electrical-Electronic	Indus-trial	Mechan-ical	Metallur-gical & Materials	Mining[c]	Petro-leum[d]	Others n.e.c.	All Combined[b]
1974	33	281	406	672	145	519	138	16	26	126	2,362
1975	30	256	370	612	132	473	126	15	24	114	2,152
1976	25	210	304	503	108	389	103	12	20	94	1,768
1977	21	178	257	426	92	329	87	10	17	79	1,496
1978	25	215	311	514	111	397	105	12	20	96	1,806
1979	31	263	380	628	135	486	129	15	24	117	2,208
1980	34	285	412	681	147	527	140	16	26	127	2,395
1981	35	295	426	705	152	545	145	17	27	131	2,478
1982	38	318	459	760	163	587	156	18	29	142	2,670
1983	39	328	474	783	168	606	161	19	30	146	2,754
Total 1974-83	311	2,629	3,799	6,284	1,353	4,858	1,290	150	243	1,172	22,089
Projected Proportion[a]	(.0141)	(.1190)	(.1720)	(.2845)	(.0612)	(.2199)	(.0584)	(.0068)	(.0110)	(.0531)	(1.0000)

[a] The projected proportions shown here (see Table 33) when multiplied by the "all combined" totals in the last column, yield a projection of that type of degree for a given year.

[b] From projections of graduates by year as found in Table 29.

[c] These projections are based upon historical data and do not take into account the probable impact of the energy crisis. The University of Pittsburgh is reactivating its program and Penn State expects to increase its output. These figures should, therefore, be approximately doubled after 1976 to reflect the program allocation. An additional factor of five engineers has been added to reflect Penn State's plans. These changes would require a reallocation of the number assigned for each specialty.

[d] These projections are invalid as predictors of baccalaureate output, since the University of Pittsburgh is shifting to a master of science degree program. They are probably good approximations, however, of the B.S. and M.S. degree supply picture for these years.

Table 35

Reallocated Projections of Engineering Baccalaureate Graduates by Degree Field Based Upon Energy Crisis Induced Growth in Mining Engineering[a]

Year	Aero-Astro-nautical	Chem-ical	Civil	Electrical-Electronic	Indus-trial	Mechan-ical	Metallur-gical & Materials	Mining	Petro-leum	Others n.e.c.	All Combined
1974	33	281	406	672	145	519	138	16	26	126	2,362
1975	30	256	370	612	132	473	126	15	24	114	2,152
1976	25	210	304	503	108	389	103	12	20	94	1,768
1977	21	176	254	422	91	326	86	25	17	78	1,496
1978	25	213	308	509	110	393	104	29	20	95	1,806
1979	31	260	376	622	134	482	128	35	24	116	2,208
1980	34	282	408	675	146	522	139	37	26	126	2,395
1981	35	292	422	699	150	540	144	39	27	130	2,478
1982	38	315	455	753	161	582	155	41	29	141	2,670
1983	39	325	470	776	166	600	160	43	30	145	2,754
Total 1974-83	311	2,610	3,773	6,243	1,343	4,826	1,283	292	243	1,165	22,089

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[a] Derived from Table 34 on the assumption that the growth pattern for mining engineering in note c of that table and the all-combined figures shown here can be accepted as valid. The other degree field figures are accordingly reapportioned.

The figures in Table 35, then, represent the total projected output of baccalaureate engineers in each specialty. As shown by Toombs,[57] not all of these B.S. degree recipients will remain in the state. In light of this, the retention rates of Table 24 are again used in Table 36 to obtain a projection of the number likely to be retained in the state, i.e., the actual supply from Pennsylvania's schools of engineering. The figures in Table 36 will be used later in making projections of need.

The Problem of In-migration

No data on in-migration by occupational category exists for Pennsylvania. To estimate the effect of in-migration one must assume that the rate of in-migration in the future will be the same as for 1971. One must assume that there was no shortage of engineers in 1971.

These assumptions allow the calculation of in-migration as a residual where in-migration is equal to demand minus available retained supply from Pennsylvania schools of engineering. The ratio of this residual to the out-migration figure of 1971 was computed for each specialty area. These ratios were then used to project in-migration by applying them to the out-migration projections arrived at earlier in this report.

PENNSYLVANIA'S UNMET NEEDS

Computing the need for engineers, including the need in each specialty area, now means combining the projections of demand computed earlier and the projections of supply. It will also be necessary to compute year-by-year projections of in-migration by the residual method described earlier.

Although the energy crisis is real and will definitely require a response, it may be instructive to consider first the projection of engineering need where no response to the energy crisis is assumed. As noted earlier, such projections assume reasonably normal economic growth, level of unemployment, etc., and may be off the mark during a recession such as the nation is now experiencing.

It has been reported, however, that the demand for engineers has held up remarkably well and began to soften only in the spring of 1975.[55] Current signs of economic recovery suggest that this softening will be short-lived.

Nonenergy Crisis Unmet Need

Tables 37 through 47 consist of projections from 1975 to 1983 for each field of engineering. The "other, n.e.c." figures are residual, rather than being composed of the figures from preceding tables, since the figure for all engineers, minus the total of all the specific categories of engineer, yields a more accurate estimate of the "other, n.e.c." engineers needed.

Table 36

Projections of Engineering Baccalaureate Graduates Retained in Each Degree Field by Year of Graduation[a]

Year	Aero-Astro-nautical	Chem-ical	Civil	Electrical-Electronic	Indus-trial	Mechan-ical	Metallur-gical & Materials	Mining	Petro-leum[c]	Others n.e.c.	All Combined
1974	14	133	163	337	77	275	82	5	9	54	1,148
1975	13	121	149	306	70	250	75	5	8	48	1,046
1976	11	99	122	252	57	206	61	4	7	40	859
1977	9	83	102	212	49	173	52	8	6	33	727
1978	11	102	124	256	58	209	61	10	7	40	878
1979	13	124	151	313	71	255	76	12	8	50	1,073
1980	15	135	164	339	78	277	82	12	9	53	1,164
1981	15	140	170	351	80	286	85	13	9	55	1,204
1982	16	150	183	379	86	309	92	14	10	60	1,298
1983	17	155	189	390	89	318	95	14	10	61	1,338
Total 1974-83	134	1,242	1,517	3,135	715	2,588	761	97	83	493	10,735
Reten-tion Rate[b]	0.429	0.482	0.407	0.508	0.540	0.536	0.600	0.333	0.333	0.427	0.486

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[a] Derived from Table 35, where the Pennsylvania retention rates from Table 24 are multiplied by the projected graduates of Table 35. The resulting row values added up to a larger figure than the all-combined estimate. The entries were, therefore, modified proportionately to add up to the "all combined" entry figure in the last column.

[b] Retention rates taken from Table 24, which summarizes an analysis of Comm-Bacc survey findings on engineers as supplied by William Toombs of The Pennsylvania State University.

[c] It is assumed here that, despite petroleum being included with chemical engineering by Toombs, the actual retention rate is more likely to be like mining's. A rate of 0.333 was used rather than the figure of 0.482 for petroleum and chemical engineers combined. Only eight per cent of the chemical and petroleum engineers combined would be classed as petroleum engineers. This puts the 0.482 figure automatically in doubt as representative of petroleum degree graduates.

Table 37

Projections of Pennsylvania Demand, Supply and Unmet Need for All Baccalaureate Degree Holding Engineers from 1975 to 1983 Made With No Assumption of an Energy Crisis

Year	Number[b]	Growth Demand[c]	Separation Demand[d]	Out-Migration Demand[e]	Total Demand	B.S. Degree Graduates[f]	Retained B.S.Degree Graduates[g]	In-Migration Supply[h]	Total Supply	Unmet Need
1971	45,803	627	734	2,203	3,564	2,482	1,205	2,359	3,564	-
	Projections									
1975	48,426	674	775	2,329	3,778	2,152	1,046	2,494	3,540	238
1976	49,116	690	786	2,362	3,838	1,768	859	2,530	3,389	449
1977	49,821	705	797	2,396	3,898	1,496	727	2,566	3,293	605
1978	50,538	717	809	2,431	3,957	1,806	878	2,604	3,482	475
1979	51,270	732	820	2,466	4,018	2,209	1,073	2,641	3,714	304
1980	52,015	745	832	2,502	4,079	2,395	1,164	2,680	3,844	235
1981	52,778	763	844	2,539	4,146	2,478	1,204	2,719	3,923	223
1982	53,553	775	857	2,576	4,208	2,670	1,298	2,759	4,057	151
1983	54,344	791	869	2,614	4,274	2,754	1,338	2,799	4,137	137
Total 1975-83		6,592	7,389	22,215	36,196	19,727	9,587	23,792	33,379	2,817

[a] 1971 is used as a base year so that retention of graduates and in-migration can be computed on a comparable basis.

[b] See Table 11.

[c] See Table 12.

[d] See Table 13.

[e] See Table 15.

[f] See Table 35.

[g] See Table 36.

[h] The assumption is made here that Pennsylvania was able to attract (in-migrate) all who were needed in 1971 to meet the discrepancy between demand and retained B.S. degree graduates and that the future estimates of in-migration would have the same relationship to out-migration in 1971, i.e., that Pennsylvania would be as successful in attracting engineers in the future.

Table 38

Projections of Pennsylvania Demand, Supply and Unmet Need for Baccalaureate Degree Holding Engineers in Astronautical-Aeronautical Engineering from 1975 to 1983 Made With No Assumption of an Energy Crisis

Year	Number[b]	Growth Demand[c]	Separations Demand[d]	Out-Migration Demand[e]	Total Demand	B.S.Degree Graduates[f]	Retained B.S.Degree Graduates[g]	In-Migration Supply[h]	Total Supply	Unmet Need
1971[a]	1,024	19	10	52	81	97	42	39	81	--
	Projections									
1975	1,101	20	11	31	87	30	13	42	55	32
1976	1,121	20	11	31	88	25	11	43	54	34
1977	1,142	21	11	32	90	21	9	43	52	38
1978	1,163	21	11	32	91	25	11	44	55	36
1979	1,184	21	12	33	93	31	13	45	58	35
1980	1,206	22	12	34	95	34	15	46	61	34
1981	1,228	22	12	34	96	35	15	47	62	34
1982	1,251	23	12	35	98	38	16	47	63	35
1983	1,274	23	13	36	101	39	17	49	66	35
Total 1975-83		193	105	298	839	278	120	406	526	313

[a] 1971 is used as a base year so that retention of graduates and in-migration can be computed on a comparable basis.

[b] See Table 11.

[c] See Table 12.

[d] See Table 13.

[e] See Table 15.

[f] See Table 35.

[g] See Table 36.

[h] The assumption is made here that Pennsylvania was able to attract (in-migrate) all who were needed in 1971 to meet the discrepancy between demand and retained B.S. degree graduates and that the future estimates of in-migration would have the same relationship to out-migration in 1971, i.e., that Pennsylvania would be as successful in attracting engineers in the future.

Table 39

Projections of Pennsylvania Demand, Supply and Unmet Need for Baccalaureate Degree Holding Engineers in Chemical Engineering from 1975 to 1983 Made With No Assumption of an Energy Crisis

Year	Number [b]	Growth Demand [c]	Separations Demand [d]	Out-Migration Demand [e]	Total Demand	B.S.Degree Graduates [f]	Retained B.S.Degree Graduates [g]	In-Migration Supply [h]	Total Supply	Unmet Need
1971[a]	3,316	-14	46	236	268	314	151	117	268	--
Projections										
1975	3,261	-14	45	232	263	256	121	115	236	27
1976	3,247	-14	45	231	262	210	99	115	214	48
1977	3,234	-13	45	230	262	176	83	114	197	65
1978	3,220	-14	44	229	259	213	102	114	216	43
1979	3,207	-13	44	228	259	260	124	113	237	22
1980	3,193	-14	44	227	257	282	135	113	248	9
1981	3,180	-13	44	226	257	292	140	112	252	5
1982	3,166	-14	44	225	255	315	150	112	262	(7)[i]
1983	3,153	-13	43	224	254	325	155	111	266	(12)
Total 1975-83		-122	398	2,052	2,328	2,329	1,109	1,019	2,128	219

[a] 1971 is used as a base year so that retention of graduates and in-migration can be computed on a comparable basis.

[b] See Table 11.

[c] See Table 12.

[d] See Table 13.

[e] See Table 15.

[f] See Table 35.

[g] See Table 36.

[h] The assumption is made here that Pennsylvania was able to attract (in-migrate) all who were needed in 1971 to meet the discrepancy between demand and retained B.S. degree graduates and that the future estimates of in-migration would have the same relationship to out-migration in 1971, i.e., that Pennsylvania would be as successful in attracting engineers in the future.

[i] Figures in parentheses represent surplus conditions, i.e., no unmet need, and are not subtracted from the total of unmet need since they would not in-migrate.

Table 40

Projections of Pennsylvania Demand, Supply and Unmet Need for Baccalaureate Degree Holding Engineers in Civil Engineering from 1975 to 1983 Made With No Assumption of an Energy Crisis

Year	Number [b]	Growth Demand [c]	Separations Demand [d]	Out-Migration Demand [e]	Total Demand	B.S. Degree Graduates [f]	Retained B.S. Degree Graduates [g]	In-Migration Supply [h]	Total Supply	Unmet Need
1971[a]	5,668	95	120	197	412	346	141	271	412	--
	Projections									
1975	6,064	102	129	210	441	370	149	289	438	3
1976	6,167	103	131	214	448	304	122	294	416	32
1977	6,272	105	133	218	456	254	102	300	402	54
1978	6,379	107	135	221	463	308	124	304	428	35
1979	6,488	109	137	225	471	376	151	310	461	10
1980	6,598	110	140	229	479	408	164	315	479	0
1981	6,711	113	142	233	488	422	170	321	491	(3)[i]
1982	6,825	114	145	237	496	455	183	326	509	(13)
1983	6,941	116	147	241	504	470	189	332	521	(17)
Total 1975–83		979	1,239	2,028	4,246	3,367	1,354	2,791	4,246	134

[a] 1971 is used as a base year so that retention of graduates and in-migration can be computed on a comparable basis.

[b] See Table 11.

[c] See Table 12.

[d] See Table 13.

[e] See Table 15.

[f] See Table 35.

[g] See Table 36.

[h] The assumption is made here that Pennsylvania was able to attract (in-migrate) all who were needed in 1971 to meet the discrepancy between demand and retained B.S. degree graduates and that the future estimates of in-migration would have the same relationship to out-migration in 1971, i.e., that Pennsylvania would be as successful in attracting engineers in the future.

[i] Figures in parentheses represent surplus conditions, i.e., no unmet need, and are not subtracted from the total of unmet need since they would not in-migrate.

Table 41

Projections of Pennsylvania Demand, Supply and Unmet Need for Baccalaureate Degree Holding Engineers in Electrical-Electronic Engineering from 1975 to 1983 Made With No Assumption of an Energy Crisis

Year	Number[b]	Growth Demand[c]	Separation Demand[d]	Out-Migration Demand[e]	Total Demand	B.S. Degree Graduates[f]	Retained B.S. Degree Graduates[g]	In-Migration Supply[h]	Total Supply	Unmet Need
1971	9,873	159	131	482	772	6[illegible]	326	446	772	-
	Projections									
1975	10,534	169	140	514	823	612	306	475	781	42
1976	10,706	172	142	522	836	503	252	483	735	101
1977	10,881	175	145	531	851	422	212	491	703	148
1978	11,059	178	147	540	865	509	256	500	756	109
1979	11,240	181	149	548	878	622	313	507	820	58
1980	11,423	183	152	557	892	675	339	515	854	38
1981	11,610	187	154	567	908	699	351	524	875	33
1982	11,800	190	157	576	923	753	379	533	912	11
1983	11,992	192	159	585	936	776	390	541	931	5
Total 1975-83		1,627	1,345	4,940	7,912	5,571	2,798	4,569	7,367	545

[a] 1971 is used as a base year so that retention of graduates and in-migration can be computed on a comparable basis.

[b] See Table 11.

[c] See Table 12.

[d] See Table 13.

[e] See Table 15.

[f] See Table 35.

[g] See Table 36.

[h] The assumption is made here that Pennsylvania was able to attract (in-migrate) all who were needed in 1971 to meet the discrepancy between demand and retained B.S. degree graduates and that the future estimates of in-migration would have the same relationship to out-migration in 1971, i.e., that Pennsylvania would be as successful in attracting engineers in the future.

Table 42

Projections of Pennsylvania Demand, Supply and Unmet Need for Baccalaureate Degree Holding Engineers in Industrial Engineering from 1975 to 1983 Made With No Assumption of an Energy Crisis

Year	Number[b]	Growth Demand[c]	Separation Demand[d]	Out-Migration Demand[e]	Total Demand	B.S. Degree Graduates[f]	Retained B.S.Degree Graduates[g]	In-Migration Supply[h]	Total Supply	Unmet Need
1971[a]	6,486	128	97	314	539	162	87	452	539	-
	Projections									
1975	7,022	138	105	340	583	132	70	490	560	23
1976	7,163	141	107	347	5[illegible]	108	57	500	557	38
1977	7,307	144	109	354	607	91	49	510	559	48
1978	7,454	147	111	361	619	110	58	520	578	41
1979	7,603	149	113	368	630	134	71	530	601	29
1980	7,756	153	116	375	644	146	78	540	618	26
1981	7,912	156	118	383	657	150	80	552	632	25
1982	8,071	159	120	391	670	161	86	563	649	21
1983	8,233	162	123	398	683	166	89	573	662	21
Total 1975-83		1,349	1,022	3,317	5,688	1,198	638	4,778	5,416	272

[a] 1971 is used as a base year so that retention of graduates and in-migration can be computed on a comparable basis.

[b] See Table 11.

[c] See Table 12.

[d] See Table 13.

[e] See Table 15.

[f] See Table 35.

[g] See Table 36.

[h] The assumption is made here that Pennsylvania was able to attract (in-migrate) all who were needed in 1971 to meet the discrepancy between demand and retained B.S. degree graduates and that the future estimates of in-migration would have the same relationship to out-migration in 1971, i.e., that Pennsylvania would be as successful in attracting engineers in the future.

Table 43

Projections of Pennsylvania Demand, Supply and Unmet Need for Baccalaureate Degree Holding Engineers in Mechanical Engineering from 1975 to 1983 Made With No Assumption of an Energy Crisis

Year	Number[b]	Growth Demand[c]	Separation Demand[d]	Out-Migration Demand[e]	Total Demand	B.S. Degree Graduates[f]	Retained B.S.Degree Graduates[g]	In-Migration Supply[h]	Total Supply	Unmet Need
1971[a]	6,874	37	119	299	455	591	314	141	455	-
	Projections									
1975	7,023	37	121	305	463	473	250	144	394	69
1976	7,061	38	122	307	467	389	206	145	351	116
1977	7,099	38	123	309	470	326	173	146	319	151
1978	7,138	39	123	310	472	393	209	146	355	117
1979	7,176	38	124	312	474	482	255	147	402	72
1980	7,215	39	125	314	478	522	277	148	425	53
1981	7,254	39	125	315	479	540	286	149	435	44
1982	7,293	39	126	317	482	582	309	150	459	23
1983	7,332	39	127	319	485	600	318	151	469	16
Total 1975-83		346	1,116	2,808	4,270	4,307	2,283	1,326	3,609	661

[a] 1971 is used as a base year so that retention of graduates and in-migration can be computed on a comparable basis.

[b] See Table 11.

[c] See Table 12.

[d] See Table 13.

[e] See Table 15.

[f] See Table 35.

[g] See Table 36.

[h] The assumption is made here that Pennsylvania was able to attract (in-migrate) all who were needed in 1971 to meet discrepancy between demand and retained B.S. degree graduates and that the future estimates of in-migration would have the same relationship to out-migration in 1971, i.e., that Pennsylvania would be as successful in attracting engineers in the future.

Table 44

Projections of Pennsylvania Demand, Supply and Unmet Need for Baccalaureate Degree Holding Engineers in Metallurgical and Materials Engineering from 1975 to 1983 Made With No Assumption of an Energy Crisis

Year	Number[b]	Growth Demand[c]	Separation Demand[d]	Out-Migration Demand[e]	Total Demand	B.S. Degree Graduates[f]	Retained B.S.Degree Graduates[g]	In-Migration Supply[h]	Total Supply	Unmet Need
1971[a]	1,614	10	23	87	120	142	85	35	120	--
Projections										
1975	1,654	10	24	89	123	126	75	36	111	12
1976	1,664	10	24	90	124	103	61	36	97	27
1977	1,675	11	24	91	126	86	52	37	89	37
1978	1,685	10	24	91	125	104	61	37	98	27
1979	1,696	11	24	92	127	128	76	37	113	14
1980	1,706	10	24	92	126	139	82	37	119	7
1981	1,717	11	24	93	128	144	85	37	122	6
1982	1,727	10	25	93	128	155	92	37	129	(1)[i]
1983	1,739	11	25	94	130	160	95	38	133	(3)
Total 1975-83		94	218	825	1,137	1,145	679	332	1,011	130

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[a] 1971 is used as a base year so that retention of graduates and in-migration can be computed on a comparable basis.

[b] See Table 11.

[c] See Table 12.

[d] See Table 13.

[e] See Table 15.

[f] See Table 35.

[g] See Table 36.

[h] The assumption is made here that Pennsylvania was able to attract (in-migrate) all who were needed in 1971 to meet the discrepancy between demand and retained B.S. degree graduates and that the future estimates of in-migration would have the same relationship to out-migration in 1971, i.e., that Pennsylvania would be as successful in attracting engineers in the future.

[i] Figures in parentheses represent surplus conditions, i.e., no unmet need, and are not subtracted from the total of unmet need since they would not in-migrate.

Table 45

Projections of Pennsylvania Demand, Supply and Unmet Need for Baccalaureate Degree Holding Engineers in Mining Engineering from 1975 to 1983 Made With No Assumption of an Energy Crisis

Year	Number[b]	Growth Demand[c]	Separation Demand[d]	Out-Migration Demand[e]	Total Demand	B.S. Degree Graduates[f]	Retained B.S.Degree Graduates[g]	In-Migration Supply[h]	Total Supply	Unmet Need
1971[a]	264	0	10	18	28	18	6	22	28	--
Projections										
1975	265	0	10	18	28	15	5	22	27	1
1976	266	1	10	19	30	12	4	23	27	3
1977	266	0	10	19	29	25	8	23	31	(2)[i]
1978	266	0	10	19	29	29	10	23	33	(4)
1979	267	1	10	19	30	35	12	23	35	(5)
1980	267	0	10	19	29	37	12	23	35	(6)
1981	267	0	10	19	29	39	13	23	36	(7)
1982	268	1	10	19	30	41	14	23	37	(7)
1983	268	0	10	19	29	43	14	23	37	(8)
Total 1975-83		3	90	170	263	276	92	206	298	4

[a] 1971 is used as a base year so that retention of graduates and in-migration can be computed on a comparable basis.

[b] See Table 11.

[c] See Table 12.

[d] See Table 13.

[e] See Table 15.

[f] See Table 35.

[g] See Table 36.

[h] The assumption is made here that Pennsylvania was able to attract (in-migrate) all who were needed in 1971 to meet the discrepancy between demand and retrained B.S. degree graduates and that the future estimates of in-migration would have the same relationship to out-migration in 1971, i.e., that Pennsylvania would be as successful in attracting engineers in the future.

[i] Figures in parentheses represent surplus conditions, i.e., no unmet need, and are not subtracted from the total of unmet need since they would not in-migrate.

Table 46

Projections of Pennsylvania Demand, Supply and Unmet Need for Baccalaureate Degree Holding Engineers in Petroleum Engineering from 1975 to 1983 Made with no Assumption of an Energy Crisis

Year	Number[b]	Growth Demand[c]	Separations Demand[d]	Out-Migration Demand[e]	Total Demand	B.S.Degree Graduates[f]	Retained B.S.Degree Graduates[g]	In-Migration Supply[h]	Total Supply	Unmet Need
1971[a]	71	1	1	10	12	36	12	0	12	-
	Projections									
1975	74	1	1	10	12	24	8	0	8	4
1976	75	1	1	10	12	20	7	0	7	5
1977	76	1	1	11	13	17	6	0	6	7
1978	77	1	0	11	12	20	7	0	7	5
1979	78	1	1	11	13	24	8	0	8	5
1980	79	1	1	11	13	26	9	0	9	4
1981	80	1	1	11	13	27	9	0	9	4
1982	81	1	1	11	13	29	10	0	10	3
1983	82	1	0	11	12	30	10	0	10	2
Total 1975-83		9	7	97	113	217	74	0	74	39

[a] 1971 is used as a base year so that retention of graduates and in-migration can be computed on a comparable basis.

[b] See Table 11.

[c] See Table 12.

[d] See Table 13.

[e] Although the figure for 1971 should be 5, on the basis of Table 15, the assumption that demand is equal to supply for that year in this table requires that this figure be doubled to 10, giving an out-migration rate of 0.1399 times the number of petroleum engineers in a given year, rather than the national rate of .0658 found in Table 15.

[f] See Table 35.

[g] See Table 36.

[h] The assumption is made here that Pennsylvania was able to attract (in-migrate) all who were needed in 1971 to meet the discrepancy between demand and retained B.S. degree graduates and that the future estimates of in-migration would have the same relationship to out-migration in 1971, i.e., that Pennsylvania would be as successful in attracting engineers in the future.

Table 47

Projections of Pennsylvania Demand, Supply and Unmet Need for Baccalaureate Degree Holding Engineers in Other Specialities, n.e.c., from 1975 to 1983 Made With No Assumption of an Energy Crisis [a]

Year	Number	Growth Demand	Separations Demand	Out-Migration Demand	Total Demand	B.S.Degree Graduates	Retained B.S.Degree Graduates [c]	In-Migration Supply [d]	Total Supply	Unmet Need
1971 [b]	10,613	192	177	508	877	135	58	819	877	--
	Projections									
1975	11,428	211	189	580	980	114	49	935	984	(4)[e]
1976	11,646	218	193	591	1,002	94	40	953	993	9
1977	11,869	223	196	601	1,020	78	35	969	1,004	16
1978	12,097	228	204	617	1,049	95	41	995	1,036	13
1979	12,331	234	206	630	1,070	116	55	1,015	1,070	0
1980	12,572	241	208	644	1,093	126	60	1,038	1,098	(5)
1981	12,818	247	214	658	1,119	130	66	1,061	1,127	(8)
1982	13,071	252	217	672	1,141	141	88	1,083	1,171	(30)
1983	13,320	260	222	687	1,169	145	102	1,107	1,209	(40)
Total 1975-83		2,114	1,849	5,680	9,643	1,039	536	9,156	9,692	38

[a] All data in this table are a result of subtracting the specific speciality values in the preceding tables from those for all specialities combined with the exception of total demand, total supply, retained B.S. degree graduates, in-migration supply and unmet need, which were computed as in the preceding tables unless otherwise indicated here.

[b] Base year for computing migration.

[c] Based upon a retention rate of 0.427 from Table 22 with surpluses from preceding tables added.

[d] Computed by using ratio of 819/508 = 1.612 and multiplying it times the out-migration demand figures as in preceding tables.

[e] Figures in parentheses represent surplus conditions, i.e., no unmet need, and are not subtracted from the total of unmet need since they would not in-migrate.

Energy Crisis Unmet Need

Tables 48 through 58 similarly consist of projections from 1975 to 1983 but they are made on an assumption that a major response to the energy crisis will begin in 1976 and that the response will create a sharp upturn in demand and in the need for engineers. As before, the "other, n.e.c." category is a residual of the figures for all engineers minus the total of the specific categories of engineer.

A Summary of the Unmet Need Findings

Table 59 summarizes, by projection year and category of engineer, the unmet need estimates that were made with no assumption of a response to the energy crisis. Table 60 summarizes in a similar fashion the unmet needs foreseen under the assumption of a major response to the energy crisis in 1976.

Table 61 compares the two sets of projections (energy crisis versus nonenergy crisis) using total unmet need estimates for 1975-1983. The energy crisis is seen as producing an overall 185.8 per cent increase in the unmet need for engineers in general, with particularly dramatic effects in the case of mining engineering (3,550 per cent), electrical-electronic engineering (283.7 per cent), mechanical engineering (277.8 per cent), civil engineering (213.4 per cent), and engineers, other, n.e.c. (188.8 per cent).

IMPLICATIONS FOR SCHOOLS OF ENGINEERING

The overall findings suggest an immediate, short-term, acute shortage of engineers followed by an amelioration of the shortage at about 1983 (energy crisis assumption). However, the long-term implications of Table 29 and of as-yet-unpublished population growth projections by the Bureau of Information Systems suggest a continued--and yet possibly increasing--unmet need for engineers well beyond 1983 unless something drastic happens to reduce the anticipated long-term growth of the economy. The solution seems to be the increased recruitment of more women and ethnic minorities as well as those males posessing the required aptitudes for engineering. The bureau's projected drop in college-age population (unpublished) is so great that even such recruitments may not suffice. (See Tables 62 and 63.)

Since only a fraction of the population possesses the aptitudes needed to sucessfully complete the engineering or scientific curricula, any attempt to recruit a larger proportion of the population (open admission, etc.) in order to compensate for falling enrollments is not likely to result in a marked increase in engineering degree output. Those with the requisite engineering and scientific aptitudes do not tend to be marginal aptitude students and are unlikely to be recruited under a program of open admissions.

More to the point will be continued efforts to recruit talented women and minority group individuals who have requisite aptitudes but who, in the past, would not have considered engineering as a major.

Table 48

Projections of Pennsylvania Demand, Supply and Unmet Need for All Baccalaureate Degree Holding Engineers from 1975 to 1983 Assuming a Response to the Energy Crisis as of 1976

Year	Number [b]	Growth Demand [c]	Separations Demand [d]	Out-Migration Demand [e]	Total Demand	B.S.Degree Graduates [f]	Retained B.S.Degree Graduates [g]	In-Migration Supply [h]	Total Supply	Unmet Need
1971[a]	45,803	627	734	2,203	3,564	2,482	1,205	2,359	3,564	--
	Projections									
1975	48,426	674	775	2,329	3,778	2,152	1,046	2,494	3,540	238
1976	49,687	1,261	786	2,390	4,437	1,768	859	2,560	3,419	1,018
1977	50,987	1,300	797	2,452	4,549	1,496	727	2,626	3,353	1,196
1978	52,326	1,339	809	2,517	4,665	1,806	878	2,696	3,574	1,091
1979	53,707	1,381	820	2,583	4,784	2,208	1,073	2,766	3,839	945
1980	55,127	1,420	832	2,652	4,904	2,395	1,164	2,840	4,004	900
1981	56,591	1,464	844	2,722	5,030	2,478	1,204	2,915	4,119	911
1982	58,101	1,510	857	2,795	5,162	2,670	1,298	2,993	4,291	871
1983	59,656	1,555	869	2,869	5,293	2,754	1,338	3,073	4,411	882
Total [illegible]975-83		11,904	7,389	23,309	42,602	19,727	9,587	24,963	34,550	8,052

[a] 1971 is used as a base year so that retention of graduates and in-migration can be computed on a comparable basis.

[b] See Table 20.

[c] See Table 21.

[d] See Table 13. Assumes same separation rate as for nonenergy crisis projections. Crisis-induced growth is seen as largely due to young graduates who are not likely to die or retire.

[e] See Table 22.

[f] See Table 35.

[g] See Table 36.

[h] The assumption is made here that Pennsylvania was able to attract (in-migrate) all who were needed in 1971 to meet the discrepancy between demand and retained B.S. degree graduates and that the future estimates of in-migration would have the same relationship to out-migration in 1971, i.e., that Pennsylvania would be as successful in attracting engineers in the future.

Table 49

Projections of Pennsylvania Demand, Supply and Unmet Need for Baccalaureate Degree Holding Engineers in Astro-Aeronautical Engineering from 1975 to 1983 Assuming a Response to the Energy Crisis as of 1976

Year	Number[b]	Growth Demand[c]	Separations Demand[d]	Out-Migration Demand[e]	Total Demand	B.S.Degree Graduates[f]	Retained B.S.Degree Graduates[g]	In-Migration Supply[h]	Total Supply	Unmet Need
1971[a]	1,024	19	10	52	81	97	42	39	81	-
	Projections									
1975	1,101	20	11	56	87	30	13	42	55	32
1976	1,121	20	11	57	88	25	11	43	54	34
1977	1,142	21	11	58	90	21	9	43	52	38
1978	1,163	21	11	59	91	25	11	44	55	36
1979	1,184	21	12	60	93	31	13	45	58	35
1980	1,206	21	12	61	95	34	15	46	61	34
1981	1,228	22	12	62	96	35	15	47	62	34
1982	1,251	23	12	63	98	38	16	47	63	35
1983	1,274	23	13	65	101	39	17	49	66	35
Total 1975-83		192	105	541	839	278	120	406	526	319

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[a] 1971 is used as a base year so that retention of graduates and in-migration can be computed on a comparable basis.

[b] See Table 20.

[c] See Table 21.

[d] See Table 13 . Assumes same separation rate as for nonenergy crisis projections. Crisis induced growth is seen as largely due to young graduates who are not likely to die or retire.

[e] See Table 22.

[f] See Table 35.

[g] See Table 36.

[h] The assumption is made here that Pennsylvania was able to attract (in-migrate) all who were needed in 1971 to meet the discrepancy between demand and retained B.S. degree graduates and that the future estimates of in-migration would have the same relationship to out-migration in 1971, i.e., that Pennsylvania would be as successful in attracting engineers in the future.

Table 50

Projections of Pennsylvania Demand, Supply and Unmet Need for Baccalaureate Degree Holding Engineers in Chemical Engineering from 1975 to 1983 Assuming a Response to the Energy Crisis as of 1976

Year	Number[b]	Growth Demand[c]	Separations Demand[d]	Out-Migration Demand[e]	Total Demand	B.S.Degree Graduates[f]	Retained B.S.Degree Graduates[g]	In-Migration Supply[h]	Total Supply	Unmet Need
1971[a]	3,316	-14	46	236	268	14	151	117	268	-
	Projections									
1975	3,261	-14	45	232	263	256				
1976	3,279	18	45	233	296	210	121	115	236	27
1977	3,297	18	45	235	298	176	99	116	215	81
1978	3,315	18	44	236	298	213	83	117	200	98
1979	3,334	19	44	237	300	260	102	117	219	79
1980	3,352	18	44	239	301	282	124	118	242	58
1981	3,370	18	44	240	302	292	135	118	253	48
1982	3,389	19	44	241	304	315	140	119	259	43
1983	3,408	19	43	243	305	325	150	119	269	35
							155	120	275	30
Total 1975-83		133	398	2,136	2,667	2,329	1,109	1,059	2,168	499

[a] 1971 is used as a base year so that retention of graduates and in-migration can be computed on a comparable basis.

[b] See Table 20.

[c] See Table 21.

[d] See Table 13 . Assumes same separation rate as for nonenergy crisis projections. Crisis induced growth is seen as largely due to young graduate who are not likely to die or retire.

[e] See Table 22.

[f] See Table 35.

[g] See Table 36.

[h] The assumption is made here that Pennsylvania was able to attract (in-migrate) all who were needed in 1971 to meet the discrepancy between demand and retained B.S. degree graduates and that the future estimates of in-migration would have the same relationship to out-migration in 1971, i.e., that Pennsylvania would be as successful in attracting engineers in the future.

Table 51

Projections of Pennsylvania Demand, Supply and Unmet Need for Baccalaureate Degree Holding Engineers in Civil Engineering from 1975 to 1983 Assuming a Response to the Energy Crisis as of 1976

Year	Number[b]	Growth Demand[c]	Separations Demand[d]	Out-Migration Demand[e]	Total Demand	B.S.Degree Graduates[f]	Retained B.S.Degree Graduates[g]	In-Migration Supply[h]	Total Supply	Unmet Need
1971[a]	5,668	95	120	197	412	346	141	271	412	-
	Projections									
1975	6,064	102	129	210	441	370	149	289	438	3
1976	6,204	140	131	215	486	304	122	296	418	68
1977	6,347	143	133	220	496	254	102	303	405	91
1978	6,493	146	135	225	506	308	124	309	433	73
1979	6,643	150	137	230	517	376	151	316	467	50
1980	6,796	153	140	236	529	408	164	325	489	40
1981	6,953	157	142	241	540	422	170	331	501	39
1982	7,113	160	145	247	552	455	183	340	523	29
1983	7,277	164	147	252	563	470	189	347	536	27
Total 1975-83		1,315	1,239	2,076	4,630	3,367	1,354	2,856	4,210	420

[a] 1971 is used as a base year so that retention of graduates and in-migration can be computed on a comparable basis.

[b] See Table 20.

[c] See Table 21.

[d] See Table 13 . Assumes same separation rate as for nonenergy crisis projections. Crisis-induced growth is seen as largely due to young graduates, who are not likely to die or retire.

[e] See Table 22.

[f] See Table 35.

[g] See Table 36.

[h] The assumption is made here that Pennsylvania was able to attract (in-migrate) all who were needed in 1971 to meet the discrepancy between demand and retained B.S. degree graduates and that the future estimates of in-migration would have the same relationship to out-migration in 1971, i.e., that Pennsylvania would be as successful in attracting engineers in the future.

Table 52

Projections of Pennsylvania Demand, Supply and Unmet Need for Baccalaureate Degree Holding Engineers in Electrical-Electronic Engineering from 1975 to 1983 Assuming a Response to the Energy Crisis as of 1976

Year	Number[b]	Growth Demand[c]	Separations Demand[d]	Out-Migration Demand[e]	Total Demand	B.S.Degree Graduates[f]	Retained B.S.Degree Graduates[g]	In-Migration Supply[h]	Total Supply	Unmet Need
1971[a]	9,873	159	131	482	772	641	326	446	772	--
Projections										
1975	10,534	171	140	514	825	612	306	475	781	44
1976	10,867	333	142	530	1,005	503	252	490	742	263
1977	11,211	344	145	547	1,036	422	212	506	718	318
1978	11,565	354	147	564	1,065	509	256	522	778	287
1979	11,931	366	149	582	1,097	622	313	538	851	246
1980	12,308	377	152	600	1,129	675	339	555	894	235
1981	12,697	389	154	620	1,163	699	351	574	925	238
1982	13,099	402	157	639	1,198	753	379	591	970	228
1983	13,513	414	159	659	1,232	776	390	610	1,000	232
Total 1975-83		3,150	1,345	5,255	9,750	5,571	2,798	4,861	7,659	2,091

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[a] 1971 is used as a base year so that retention of graduates and in-migration can be computed on a comparable basis.

[b] See Table 20.

[c] See Table 21.

[d] See Table 13 . Assumes same separation rate as for nonenergy crisis projections. Crisis-induced growth is seen as largely due to young graduates, who are not likely to die or retire.

[e] See Table 22.

[f] See Table 35.

[g] See Table 36.

[h] The assumption is made here that Pennsylvania was able to attract (in-migrate) all who were needed in 1971 to meet the discrepancy between demand and retained B.S. degree graduates and that the future estimates of in-migration would have the same relationship to out-migration in 1971, i.e., that Pennsylvania would be as successful in attracting engineers in the future.

Table 53

Projections of Pennsylvania Demand, Supply and Unmet Need for Baccalaureate Degree Holding Engineers in Industrial Engineering from 1975 to 1983 Assuming a Response to the Energy Crisis as of 1976

Year	Number [b]	Growth Demand [c]	Separations Demand [d]	Out-Migration Demand [e]	Total Demand	B.S.Degree Graduates [f]	Retained B.S.Degree Graduates [g]	In-Migration Supply [h]	Total Supply	Unmet Need
1971 [a]	6,486	128	97	314	539	162	87	452	539	--
	Projections									
1975	7,022	138	105	340	583	132	70	489	559	24
1976	7,173	151	107	347	605	108	57	499	556	49
1977	7,327	154	109	355	618	91	49	511	560	58
1978	7,485	158	111	362	631	110	58	521	579	52
1979	7,646	161	113	370	644	134	71	532	603	41
1980	7,810	164	116	378	658	146	78	544	622	36
1981	7,978	168	118	386	672	150	80	556	636	36
1982	8,149	171	120	394	685	161	86	567	653	32
1983	8,325	176	123	403	702	166	89	580	669	33
Total 1975-83		1,441	1,022	3,335	5,798	1,198	638	4,799	5,437	361

[a] 1971 is used as a base year so that retention of graduates and in-migration can be computed on a comparable basis.

[b] See Table 20.

[c] See Table 21.

[d] See Table 13 . Assumes same separation rate as for nonenergy crisis projections. Crisis-induced growth is seen as largely due to young graduates, who are not likely to die or retire.

[e] See Table 22.

[f] See Table 35.

[g] See Table 36.

[h] The assumption is made here that Pennsylvania was able to attract (in-migrate) all who were needed in 1971 to meet discrepancy between demand and retained B.S. degree graduates and that the future estimates of in-migration would have the same relationship to out-migration in 1971, i.e, that Pennsylvania would be as successful in attracting engineers in the future.

Table 54

Projections of Pennsylvania Demand, Supply and Unmet Need for Baccalaureate Degree Holding Enginners in Mechanical Engineering from 1975 to 1983 Assuming a Response to the Energy Crisis as of 1976

Year	Number [b]	Growth Demand [c]	Separations Demand [d]	Out-Migration Demand [e]	Total Demand	B.S.Degree Graduates [f]	Retained B.S.Degree Graduates [g]	In-Migration Supply [h]	Total Supply	Unmet Need
1971[a]	6,874	37	119	299	455	591	314	141	455	--
	Projections									
1975	7,023	37	121	305	463	473	250	144	394	69
1976	7,242	219	122	315	656	389	206	149	355	301
1977	7,469	227	123	325	675	326	173	153	326	349
1978	7,702	233	123	335	691	393	209	158	367	324
1979	7,943	241	124	345	710	482	255	163	418	292
1980	8,191	248	125	356	729	522	277	168	445	284
1981	8,447	256	125	367	748	540	286	173	459	289
1982	8,711	264	126	379	769	582	309	179	488	281
1983	8,983	272	127	391	811	600	318	185	503	308
Total 1975-83		1,997	1,116	3,118	6,252	4,307	2,283	1,472	3,755	2,497

[a] 1971 is used as a base year so that retention of graduates and in-migration can be computed on a comparable basis.

[b] See Table 20.

[c] See Table 21.

[d] See Table 13 . Assumes same separation rate as for nonenergy crisis projections. Crisis-induced growth is seen as largely due to young graduates, who are not likely to die or retire.

[e] See Table 22.

[f] See Table 35.

[g] See Table 36.

[h] The assumption is made here that Pennsylvania was able to attract (in-migrate) all that were needed in 1971 to meet the discrepancy between demand and retained B.S. degree graduates and that the future estimates of in-migration would have the same relationship to out-migration in 1971, i.e, that Pennsylvania would be as successful in attracting engineers in the future.

Table 55

Projections of Pennsylvania Demand, Supply and Unmet Need for Baccalaureate Degree Holding Engineers in Metallurgical and Materials Engineering from 1975 to 1983 Assuming Response to the Energy Crisis as of 1976

Year	Number[b]	Growth Demand[c]	Separations Demand[d]	Out-Migration Demand[e]	Total Demand	B.S.Degree Graduates[f]	Retained B.S.Degree Graduates[g]	In-Migration Supply[h]	Total Supply	Unmet Need
1971[a]	1,604	10	23	87	120	142	85	35	120	-
	Projections									
1975	1,654	10	24	89	123	126	75	36	111	12
1976	1,673	19	24	90	133	103	61	36	97	36
1977	1,692	19	24	91	134	86	52	37	89	45
1978	1,712	20	24	93	137	104	61	37	98	39
1979	1,732	20	24	94	138	128	76	38	114	24
1980	1,752	20	24	95	139	139	82	38	120	19
1981	1,772	20	24	96	140	144	85	39	124	16
1982	1,793	21	25	97	143	155	92	39	131	12
1983	1,814	21	25	98	144	160	95	39	134	10
Total 1975-83		170	218	843	1,231	1,145	679	339	1,018	213

[a] 1971 is used as a base year so that retention of graduates and in-migration can be computed on a comparable basis.

[b] See Table 20.

[c] See Table 21.

[d] See Table 13 . Assumes same separation rate as for nonenergy crisis projections. Crisis-induced growth is seen as largely due to young graduates, who are not likely to die or retire.

[e] See Table 22.

[f] See Table 35.

[g] See Table 36.

[h] The assumption is made here that Pennsylvania was able to attract (in-migrate) all who were needed in 1971 to meet the discrepancy between demand and retained B.S. degree graduates and that the future estimates of in-migration would have the same relationship to out-migration in the 1971, i.e, that Pennsylvania would be as susscessful in attracting engineers in the future.

Table 56

Projections of Pennsylvania Demand, Supply and Unmet Need for Baccalaureate Degree Holding Engineers in Mining Engineering from 1975 to 1983 Assuming a Response to the Energy Crisis as of 1976

Year	Number [b]	Growth Demand [c]	Separations Demand [d]	Out-Migration Demand [e]	Total Demand	B.S.Degree Graduates [f]	Retained B.S.Degree Graduates [g]	In-Migration Supply [h]	Total Supply	Unmet Need
1971 [a]	264	0	10	18	28	18	6	22	28	--
Projections										
1975	265	0	10	18	28	15	5	22	27	1
1976	284	19	10	20	49	12	4	24	28	21
1977	304	20	10	21	51	25	8	26	34	17
1978	326	22	10	23	55	29	10	28	38	17
1979	350	24	10	24	58	35	12	29	41	17
1980	375	25	10	26	61	37	12	32	44	17
1981	402	27	10	28	65	39	13	34	47	18
1982	431	29	10	30	69	41	14	37	51	18
1983	462	31	10	32	73	43	14	39	53	20
Total 1975-83		197	90	222	509	276	92	271	363	146

[a] 1971 is used as a base year so that retention of graduates and in-migration can be computed on a comparable basis.

[b] See Table 20.

[c] See Table 21.

[d] See Table 13 . Assumes same separation rate as for nonenergy crisis projections. Crisis-induced growth is seen as largely due to young graduates, who are not likely to die or retire.

[e] See Table 22.

[f] See Table 35.

[g] See Table 36.

[h] The assumption is made here that Pennsylvania was able to attract (in-migrate) all who were needed in 1971 to meet the discrepancy between demand and retained B.S. degree graduates and that the future estimates of in-migration would have the same relationship to out-migration in 1971, i.e., that Pennsylvania would be as successful in attracting engineers in the future.

Table 57

Projections of Pennsylvania Demand, Supply and Unmet Need for Baccalureate Degree Holding Engineers in Petroleum Engineering from 1975 to 1983 Assuming a Response to the Energy Crisis as of 1976

Year	Number [b]	Growth Demand [c]	Separations Demand [d]	Out-Migration Demand [e]	Total Demand	B.S.Degree Graduates[f]	Retained B.S.Degree Graduates[g]	In-Migration Supply [h]	Total Supply	Unmet Need
1971[a]	71	1	1	10	12	36	12	0	12	0
Projections										
1975	74	1	1	10	12	24	8	0	8	4
1976	76	2	1	11	14	20	7	0	7	7
1977	79	3	1	11	15	17	6	0	6	9
1978	81	2	0	11	13	20	7	0	7	6
1979	84	3	1	12	16	24	8	0	8	8
1980	87	3	1	12	16	26	9	0	9	7
1981	90	3	1	13	17	27	9	0	9	8
1982	93	3	1	13	17	29	10	0	10	7
1983	96	3	0	13	16	30	10	0	10	6
Total 1975-83		23	7	106	136	217	74	0	74	62

[a] 1971 is used as a base year so that retention of graduates and in-migration can be computed on a comparable basis.

[b] See Table 20.

[c] See Table 21.

[d] See Table 13 . Assumes same separation rate as for nonenergy crisis projections. Crisis-induced growth is seen as largely due to young graduates, who are not likely to die or retire.

[e] Although the figure for 1971 should be 5, on the basis of Table 22 , the assumption of demand being equal to supply for that year in this table requires that this figure be doubled to 10, giving an out-migration rate of 0.1399 times the number of petroleum engineers in a given year, rather than the national rate of .0658 found in Table 22.

[f] See Table 35.

[g] See Table 36.

[h] The assumption is made here that Pennsylvania was able to attract (in-migrate) all who were needed in 1971 to meet the discrepancy between demand and retained B.S. degree graduates and that the future estimates of in-migration would have the same relationship to out-migration in 1971, i.e., that Pennsylvania would be as successful in attracting engineers in the future.

Table 58

Projections of Pennsylvania Demand, Supply and Unmet Need for Baccalaureate Degree Holding Engineers in Other Engineers, n.e.c., from 1975 to 1983 Made With an Assumption of an Energy Crisis Response Beginning in 1976 [a]

Year	Number	Growth Demand	Separations Demand	Out-Migration Demand	Total Demand	B.S.Degree Graduates	Retained B.S.Degree Graduates[c]	In-Migration Supply[d]	Total Supply	Unmet Need
1971[b]	10,613	192	177	508	877	135	58	819	877	--
	Projections									
1975	11,428	209	189	555	953	114	49	895	944	9
1976	11,768	340	193	572	1,105	94	40	922	962	143
1977	12,119	351	196	589	1,136	78	33	949	982	154
1978	12,484	365	204	609	1,178	95	41	982	1,023	155
1979	12,860	376	206	629	1,211	116	50	1,014	1,064	147
1980	13,250	390	208	649	1,247	126	54	1,046	1,100	147
1981	13,654	404	214	669	1,287	130	55	1,078	1,133	154
1982	14,072	418	217	692	1,327	141	60	1,116	1,176	151
1983	14,504	432	222	713	1,367	145	62	1,149	1,211	156
Total 1975-83		3,285	1,849	5,677	10,811	1,039	444	9,151	9,595	1,216

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[a] All data in this table are a result of subtracting the specific specialty values in the preceding tables from those for all specialties combined with the exception of total demand, total supply, retained B.S. degree graduates, in-migration supply and unmet need, which were computed as in the preceding tables.

[b] Base year for computing migration.

[c] Based upon a retention rate of 0.427 from Table 24.

[d] Computed by using ratio of 819/508 = 1.612 and multiplying it by the out-migration demand figures as in preceding tables.

Table 59

A Summary of Projected Unmet Need Findings for Pennsylvania Assuming No Energy Crisis[a]

Engineering Specialty	1975	1976	1977	1978	1979	1980	1981	1982	1983	Total
Astro-Aeronautical	32	34	38	36	35	34	34	35	35	313
Chemical	27	48	65	43	22	9	5	(7)[c]	(12)[c]	219
Civil	3	32	54	35	10	0	(3)[c]	(13)[c]	(17)[c]	134
Electrical-Electronic	42	101	148	109	58	38	33	11	5	545
Industrial	23	38	48	41	29	26	25	21	21	272
Mechanical	69	116	151	117	72	53	44	23	16	661
Metallurgical/Materials	12	27	37	27	14	7	6	(1)[c]	(3)[c]	130
Mining	1	3	(2)[c]	(4)[c]	(5)[c]	(6)[c]	(7)[c]	(7)[c]	(8)[c]	4
Petroleum	4	5	7	5	5	4	4	3	2	39
Other[b]	25	45	57	62	59	64	72	58	58	500
All Combined	238	449	605	475	304	235	223	151	137	2,817

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[a] Based upon Tables 37-46,

[b] Entries modified to reflect the difference between the "all combined" entry and the total of the unmet need figures in the column rather than the unmet need entries of Table 47.

[c] Entries in parentheses indicate surplus conditions. These entries are not included in the column or row totals.

Table 60

A Summary of Projected Unmet Need Findings for Pennsylvania Assuming a Response to the Energy Crisis as of 1976[a]

Engineering Specialty	1975	1976	1977	1978	1979	1980	1981	1982	1983	Total
Astro-Aeronautical	32	34	38	36	35	34	34	35	35	319
Chemical	27	81	98	79	58	48	43	35	30	499
Civil	3	68	91	73	50	40	39	29	27	420
Electrical-Electronic	44	263	318	287	246	235	238	228	232	2,091
Industrial	24	49	58	52	41	36	36	32	33	361
Mechanical	69	301	349	324	292	284	289	281	308	2,497
Metallurgical/Materials	12	36	45	39	24	19	16	12	10	213
Mining	1	21	17	17	17	17	18	18	20	146
Petroleum	4	7	9	6	8	7	8	7	6	62
Other[b]	22	158	173	178	174	180	190	194	181	1,444
All Combined	238	1,018	1,196	1,091	945	900	911	871	882	8,052

[a] Based upon Tables 48-57.

[b] Entries modified to reflect the difference between the "all-combined" entry and the total of the unmet need figures in the column rather than the unmet need entries of Table 58.

Table 61

A Summary of the Total Unmet Need Findings of Tables 37 Through 60 for Pennsylvania from 1975 to 1983

Engineering Specialty	Nonenergy Crisis Unmet Need	Energy Crisis Unmet Need	Percentage Increase
Astro-Aeronautical	313	319	1.9
Chemical	219	499	127.9
Civil	134	420	213.4
Electrical-Electronic	545	2,091	283.7
Industrial	272	361	32.7
Mechanical	661	2,497	277.8
Metallurgical-Materials	130	213	63.8
Mining	4	62	3,550.0
Petroleum	39	62	59.0
Other	38(500)[a]	1,216(1,444)[a]	3,100.0(188.8)
All Combined	2,817	8,052	185.8

[a] A corrected figure to account for the discrepancy between the total of the separate specialties and the independently arrived at "all Combined" figure has been placed in the parentheses (see Tables 59 and 60).

Table 62

Projected Change in Age Groupings That Are Primary Sources of Students for Each Level of Education[a]

Educational Level	Age Range	Year					1970-9
		1970	1975	1980	1985	1990	% Chang
Preschool	0-4	926,187	825,471	719,170	664,470	622,990	-32.
Kindergarten	5	216,551	181,390	161,665	140,847	130,134	-39.
Elementary	6-11	1,333,626	1,157,609	1,008,559	885,933	801,546	-39.
Junior High	12-14	701,132	648,075	542,848	483,818	421,515	-39.
High School	15-17	645,258	699,538	646,600	541,612	482,720	-25.
College	18-21	771,141	894,198	894,873	739,782	680,913	-11.
Graduate School	22-29	1,169,053	1,388,736	1,594,021	1,660,664	1,572,015	+34.
Adult Education (In-service)	30-64	4,758,834	4,822,095	4,980,775	5,196,308	5,476,293	+15.
Adult Education	65 over	1,272,126	1,453,578	1,624,360	1,804,413	1,889,936	+48.

[a]Developed from projections by John Senier of the Bureau of Information Systems, Pennsylvania Department of Education assuming a rectangular distribution within each five- or 10-year block is assumed in Senier's table.

Table 63

Projected College Age Percentage Growth for Various Base Years[a]

Base Year	Projection Year			
	1975	1980	1985	1990
	%	%	%	%
1970	15.96	16.05	- 4.07	-11.70
1975		0.08	-11.68	-23.85
1980			-17.33	-23.91
1985				- 7.96

[a]Based upon the figures in Table 62.

Another helpful factor may be the possible 1980s surplus of scientists and of Ph.d.'s in both science and engineering now projected by the Federal Bureau of Labor Statistics.[28,46,68] Students who normally would have opted for the biological and physical sciences may instead find engineering an attractive alternative.

One can but hope that the current trend toward lower mathematical aptitude as measured by the Scholastic Aptitude Tests (SAT)[53] will slow or reverse itself and that the findings of the National Assessment Studies indicating a lowering of achievement in basic math[41] and science knowledge[43] do not reflect a long-term, negative trend that could affect engineering enrollments.

There can be no doubt that those students who are recruited, and possess the requisite aptitudes, will have to be taught, using the most effective techniques the schools can devise to reduce the attrition that normally occurred in the past between the freshman and senior years. In the face of rising demand and lower enrollments engineering cannot affort to be known as the curriculum from which students typically transfer.

LIMITATIONS OF THIS STUDY

Aside from the obvious limitations imposed by the necessity of approximating the migration variable (both in- and out-migration) and by the assumptions that had to be made about the distribution of the B.S. degree specialties in the future, there are several other limitations that should be kept in mind.

1. The methodology used by the Bureau of Labor Statistics to forecast presupposes relatively normal economic and technological growth, much like that of the past decade (1960-1970).

2. The energy crisis corrections introduced here represent only one possible scenario. The scenario used here is the one foreseen by the National Planning Association. It also assumes a one-to-one relationship between the national change pattern and the Pennsylvania pattern, i.e., Pennsylvania is assumed to be a microcosm of the nation, well impacted by the energy crisis. For example, the members of the Pennsylvania Association of Engineering Colleges have expressed the opinion that the demand for civil engineers due to energy related construction will exceed that shown here.

3. The estimates of the number of degree-holding engineers in Pennsylvania may not approximate national patterns.

4. Demand for engineers in a given year is met, in part, by those with newly received masters and doctoral degrees, but to an undetermined degree. The assumption has been made in this study that most, if not all, graduate students in engineering are already in the labor market and that the recipient of a baccalaureate will, in any case, enter the labor market very shortly after graduation.

5. If a lack of degree-level engineers persists, the technology degree recipient (less-than-four-years associate degree) will fill the need, which means that employers will downgrade their requirements. However, no effort was made here to assess the growth of this type of engineering-related employment, since the intent of this study is to assess the need for college graduates in engineering. Undoubtedly, the student with marginal aptitude could fill expanded openings in the engineering technology curriculum and could also fill, with some degree of competence, shortage induced employer needs either directly (title of engineer) or as part of an engineering team headed by a senior, degree-holding engineer.

6. These findings may be a systematic underestimate of the need since it was not possible to estimate the demand due to occupational migration, e.g., possibly 5 per cent of all engineers leave engineering as such and become administrators, etc., and are no longer labeled as engineers. The rate for different types of engineers is not known and the 5 per cent figure is a tentative one reported to the author by federal researchers in this area.

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